

# Quality Improvement – The Six Sigma Way

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## Abstract

*Six Sigma provides an effective mechanism to focus on customer requirements, through improvement of process quality. In the Global Engineering Development Center of Tata Consultancy Services (TCS – GEDC) at Chennai, India, Six Sigma projects are being carried out with the objective of improving on time delivery, product quality and in-process quality.*

*This paper describes the application of the Six Sigma methodology comprising the five phases – Define, Measure, Analyze, Improve and Control, by taking the example of a project, and demonstrates the benefits attained.*

## 1. Background

The Global Engineering Development Center of Tata Consultancy Services (TCS–GEDC) located at Chennai, India, has been executing projects for various businesses of General Electric Company (GE) since 1995. The projects span the areas of Engineering Design, Computer Aided Design, Finite Element Analysis, Software Development for Engineering Automation and Implementation of Product Data Management Solutions. TCS – GEDC has a number of initiatives in quality and process management and is on its journey to Level 5 of the Capability Maturity Model (CMM) enunciated by the Software Engineering Institute of Carnegie Mellon University [1]. TCS – GEDC's long association with GE has influenced it to adopt the Six Sigma Approach for making disciplined and rigorous progress in quality improvement. TCS – GEDC learns and leverages from the experience of GE in the implementation of Six Sigma Initiatives.

Six Sigma Quality quantitatively means that the average review process generates 3.4 defects per million units – where a unit can be anything ranging from a component to a line of code or an administrative form. This implies that nearly flawless execution of key processes is critical to achieve customer satisfaction and productivity growth [2].

The Six Sigma Initiatives in TCS – GEDC started in 1998, and, since then, 10 Six Sigma projects have been completed. These projects include Improvement of Schedule Compliance, Quality Compliance, Input Quality, Error Reduction, Cycle Time Reduction and Design Improvement.

At present the Six Sigma Program addresses Productivity Improvement and Defect Prevention in the projects carried out in the TCS – GEDC. The Six Sigma projects have been identified in the areas of improvement after analysis of the process and product metrics against the center level specification limits. Currently, TCS – GEDC has 6 Black Belt and 30 Green Belt ongoing projects in different Business Groups. The Green Belt Projects are derived from the analysis phase / improvement phase of the Black Belt projects.

The approach, methodology and benefits of Six Sigma is explained in this paper by taking the case of a Six Sigma project. This project is on the improvement of product quality compliance carried out in one of the Business Groups of TCS – GEDC in 1998–1999.

## 2. The Six Sigma approach

The Six Sigma Approach is customer-driven. For a business or a manufacturing process, the Sigma Capability is a metric that indicates how well the process is being performed. The higher the Sigma Capability, the better, because it measures the capability of the process to achieve defect-free-work (where a defect is anything that results in customer dissatisfaction).

**A defect is anything that  
results in customer  
dissatisfaction**

The Six Sigma Approach is also data-driven. It focuses on reducing process variation, centering the process and on optimizing the process. The emphasis is on the improvement of process capability rather than the

control of product quality, which includes the improvement of quality and reduction of cost of quality.

In short, the Six Sigma Approach focuses on:

Customer needs

Data-driven improvements

The inputs of the process

And this results in:

Reducing or eliminating defects

Reducing process variation

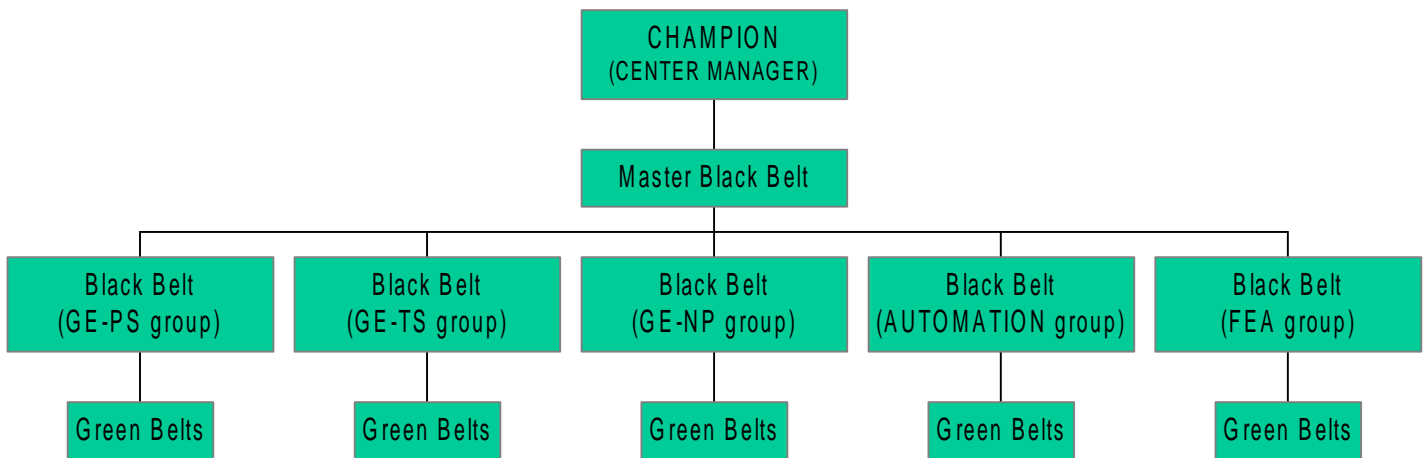
Increasing process capability

In this context, the customer requirements for our

To successfully execute these Six Sigma projects, an organization structure as shown in Figure 1-1 has been formulated. This structure consists of the following roles:

*Champion:* The Center Manager is the Champion, who facilitates the implementation / deployment of the Six Sigma Program. The Champion creates the vision, defines the path to Six Sigma Quality, measures the progress and sustains improvements.

*Master Black Belt:* The Master Black Belt is a Mentor, who develops a Six Sigma network, provides



**Figure 1-1 Organization structure for Six Sigma**

centre are -

On-Time, Accurate and Complete Customer Deliverables

Customer Responsiveness

Marketplace Competitiveness

To achieve these goals the Six Sigma approach was adopted in all the projects to pinpoint sources of errors and ways of eliminating them.

### 3. Deployment

All employees are trained on Six Sigma Quality to increase their awareness, understanding, and the day-to-day use of Six Sigma tools and processes, and their application to projects.

Six Sigma projects (quality projects) are chosen, based on customer feedback and analysis of the process metrics. Projects that have a significant customer impact and financial savings are given top priority.

training on strategies and tools, gives one-to-one support on utilization and dissemination of Six Sigma tools, and supervises the Six Sigma projects. The Master Black Belt also facilitates sharing of best practices and actively participates in the change process.

*Black Belts / Green Belts:* Black Belts / Green Belts lead process improvement teams, demonstrate credible application of Six Sigma tools, train their team members and are accountable for Six Sigma project results. While Black Belts work full-time on Six Sigma projects, the Green Belts work only part-time on the Six Sigma projects and devote the rest of their time to other projects. The Black Belts report the progress of their projects to the Master Black Belt and the Green Belts report the progress of their projects to the Black Belts. The Green Belts are expected to complete two Six Sigma projects while the Black Belts are to complete five.

The criteria for a successful Six Sigma project could be any one of the following:

- i. There is an improvement of one sigma in the process capability, if the project has started the process with less than one Sigma
- ii. There is a 50% reduction in defects, if the process has started with more than three Sigma
- iii. There is a Return on Investment of 20%.

Potential Failure Modes	Potential Causes	Current Controls	Risk Priority Number	Recommended Action
Dispatch incomplete	Work Pressure	No Control	200	Development of tools for complete delivery
PDM structure not followed	Lack of knowledge	No Control	180	PDM file handling procedure to be evolved.
Non conformance of inputs with Standards	Information not given to all team members against blindly following SIMTOs	No Control	160	Maintain a text file in pkg. directory, where a complete track of pkg. progress is recorded to address any deviations / non-conformances up front.
Incomplete dispatch	Lack of knowledge	No Control	140	Process Procedure to include all the dispatch procedures.
Non compliance to Standards	QA tool limitations	QA Tool	120	Limitations will be fixed by Jan '99 end

**Table 5 -1 Failure Modes and Effects Analysis**

#### 4. Methodology

A Six Sigma Project consists of the following phases:

*Define:* The product or process to be improved is identified. Customer needs are identified and translated into Critical to Quality Characteristics (CTQs). The problem/goal statement, the project scope, team roles and milestones are developed. A high-level process is mapped for the existing process.

*Measure:* The key internal processes that influence the CTQs are identified and the defects generated relative to the identified CTQs are measured.

*Analyze:* The objective of this phase is to understand why defects are generated. Brainstorming and statistical tools are used to identify key variables (X's) that cause defects. The output of this phase is the explanation of the variables that are most likely to affect process variation.

*Improve:* The objective of this phase is to confirm the key variables and quantify the effect of these variables on the CTQs. It also includes identifying the maximum acceptable ranges of the key variables, validating the measurement systems and modifying the existing process to stay within these ranges.

*Control:* The objective of this phase is to ensure that the modified process now enables the key variables to stay within the maximum acceptable ranges, using tools like Statistical Process Control (SPC) or simple checklists.

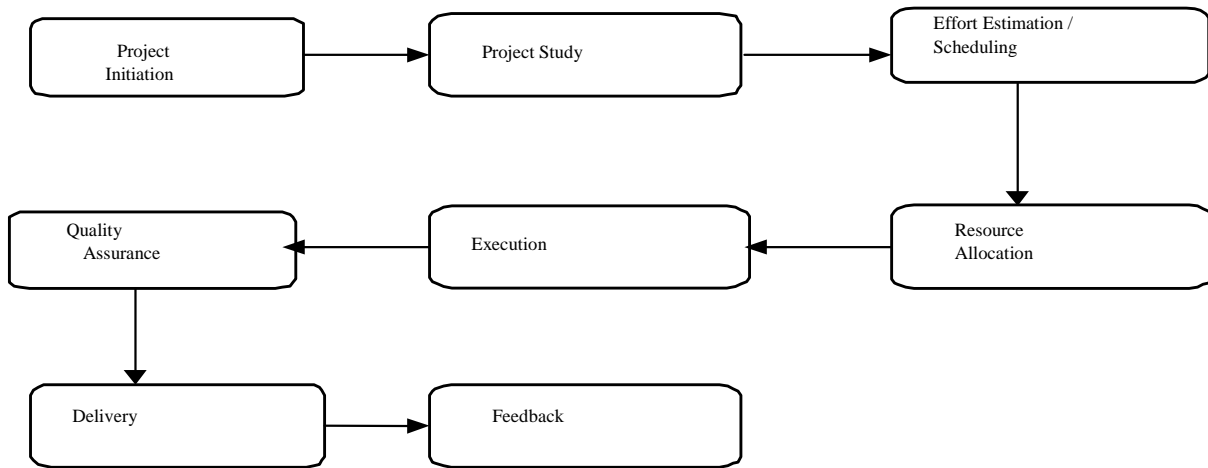
#### 5. Six Sigma project on quality compliance

This section discusses a Six Sigma project on the improvement of product quality compliance, which will give a better understanding of the approach, methodology and benefits of Six Sigma.

##### 5.1. Define phase

The project teams had the problem of field errors being reported in the deliverables. Based on the metrics for 1997, the long-term process capability for product quality was at  $3.48\sigma$ , while the short-term capability was at  $4.98\sigma$ , and the Defects Per Million Opportunities (DPMO) were at 253.

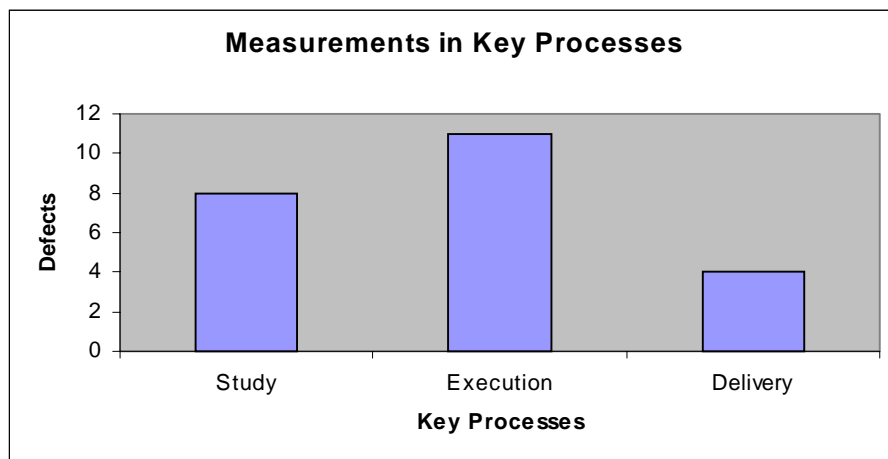
A Six Sigma approach was initiated to improve the quality of deliverables. The goal of the project was to improve the long-term process capability to more than  $4\sigma$  and to reduce the DPMO by more than 50%.



**Figure 5-1: High-level process mapping of the existing process**

The project started the Define Phase with the identification of Product Quality as the CTQ. Team

characteristic that adds or deducts value from the product, was defined, based on the opportunity



**Figure 5-2: Measurement of defects in key processes**

members from different levels namely Project Leaders, Module Leaders, Team Members and the Quality Team were identified for the Six Sigma project.

A high-level process mapping for the existing process was made as shown in Figure 5-2.

The next step was to define the measurement system. Any attribute in the deliverable sent to the customer, which does not meet the customer’s requirements, or which is not as per the Customer’s Standards was defined as a defect. For the purpose of calculating DPMO, the opportunity, which is a product or process

definition by the client [3].

**5.2. Measure phase**

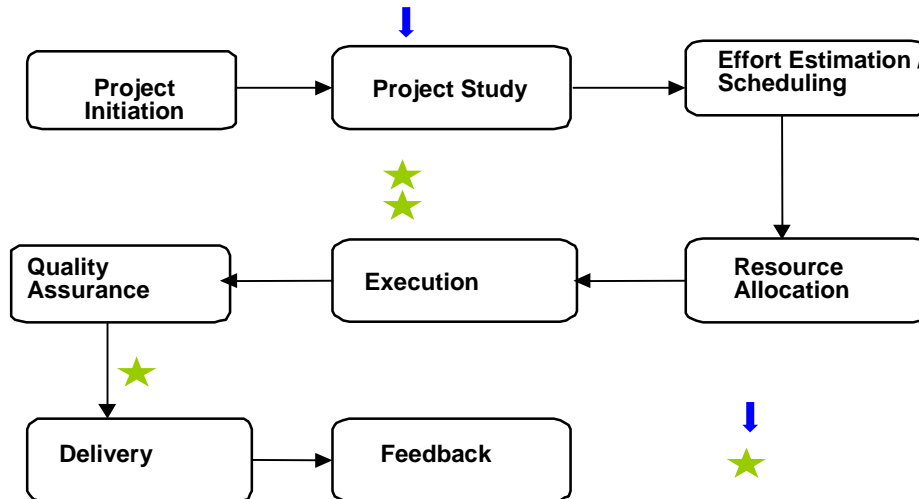
During this phase, the key processes in the project lifecycle that affect the CTQ (in this case, product quality), were identified to be project study, execution and delivery. Measurements related to the CTQ were made in these phases. The field errors reported by the client were classified as defects that have occurred in each of these processes as shown in Figure5-3.

In each of these processes, the input process variables (controllable or critical-those that show

The Input Variable — Quality of Inputs, had various attributes namely, clarity of scope definitions,

statistical significance) that affect the CTQ were identified as shown in Figure 5-4.

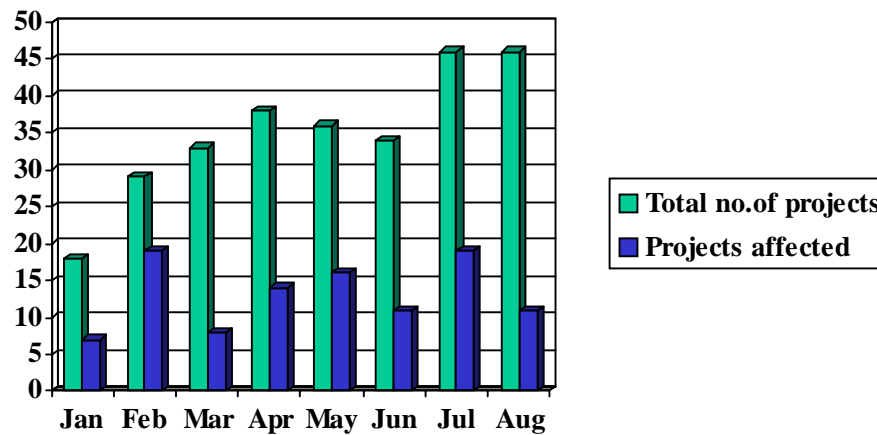
Therefore, it was decided to analyse the effect of quality of inputs separately. A Black Belt project named



**Figure 5-3 Input process variables in the Key**

completeness of inputs, and conformance of inputs to standards. This variable became a critical variable that affected the product quality, since the inputs for the projects were obtained from the customer. The projects that were affected by poor quality of inputs were measured. As depicted in Figure 5-5, a substantial number of projects were affected by poor quality of inputs in 1998.

'Analysis of Input Quality' was executed in 1998. As a result of this project, process control in the form of an input checklist was introduced at the project start-up phase, to prevent defects occurring in the project deliverables due to wrong inputs.



**Figure 5-4: Projects affected by Poor Input quality in 1998**

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### 5.3. Analyze phase

Process performance was assessed using Cause-and-Effect diagrams, to isolate key problem areas, to study the causes for the deviation from ideal performance, and

to identify if there is a relationship between the variables. Extensive brain-storming sessions were held with team members to evolve these diagrams. Figure 5-6 shows the Cause-and-Effect diagrams for one of the project teams.

The probable causes that can lead to quality non-conformance in a project during different phases of a project life cycle were listed

The Failure Modes and Effects Analysis (FMEA) was subsequently carried out to arrive at a plan for prevention of causes for failure.

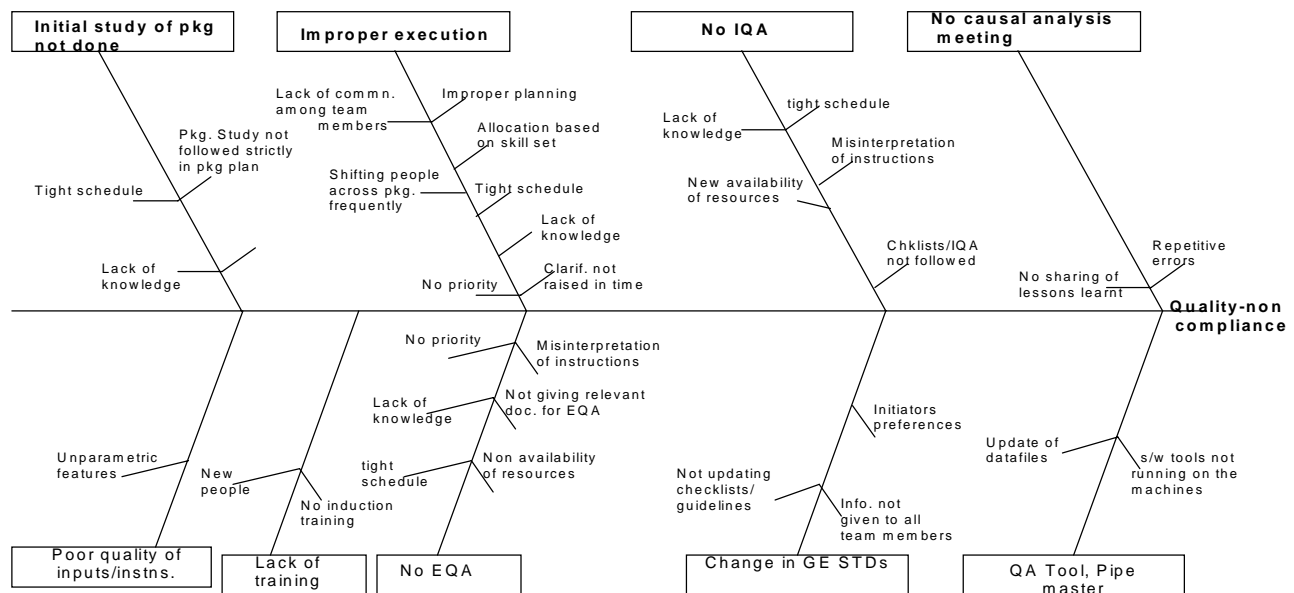
FMEA is a tool that helps prevent the occurrence of problems by:

Identifying the potential failure modes in which a process or product may fail to meet specifications, and rating the severity of the effect on the customer.

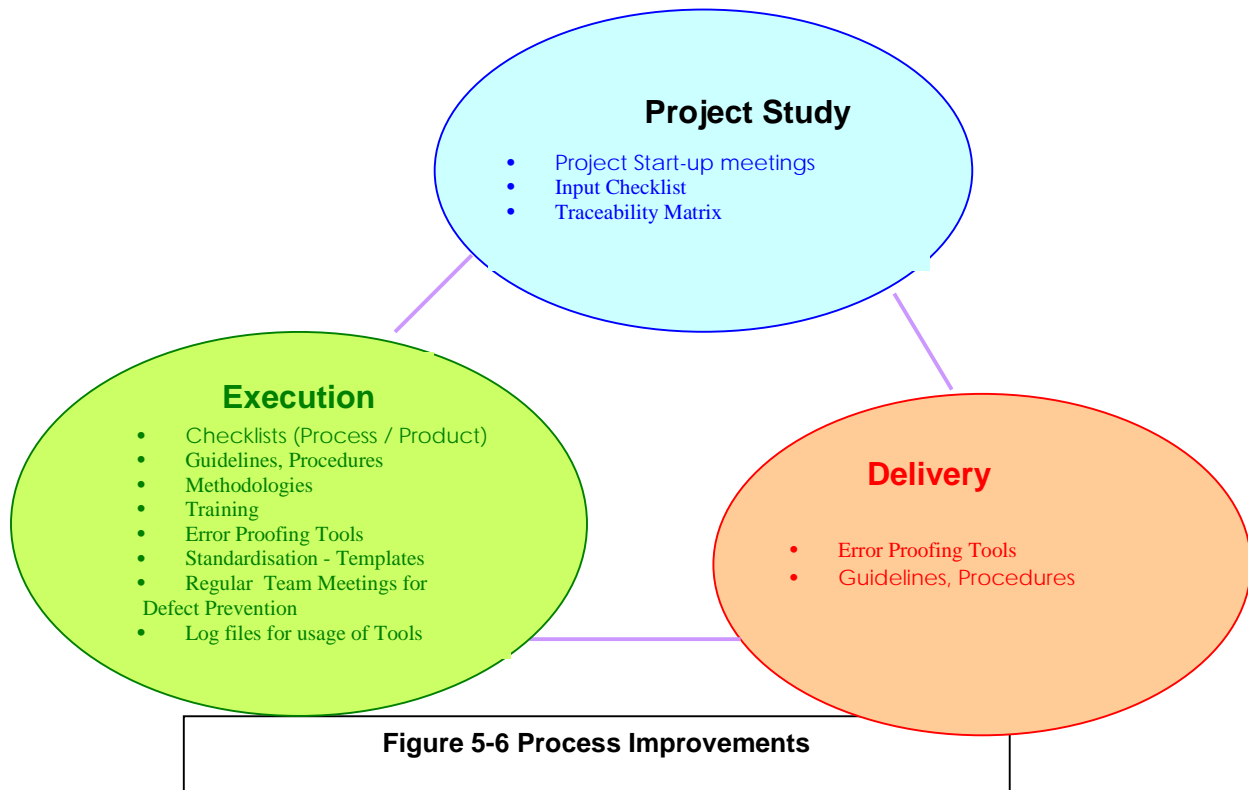
Providing an objective evaluation of the occurrence of causes

Determining the ability of the current system to detect when those causes or failure modes will occur.

Based on the above factors, a Risk Priority Number (RPN) for each failure mode is calculated [3].



**Figure 5-5 Cause & effect diagram for product quality**



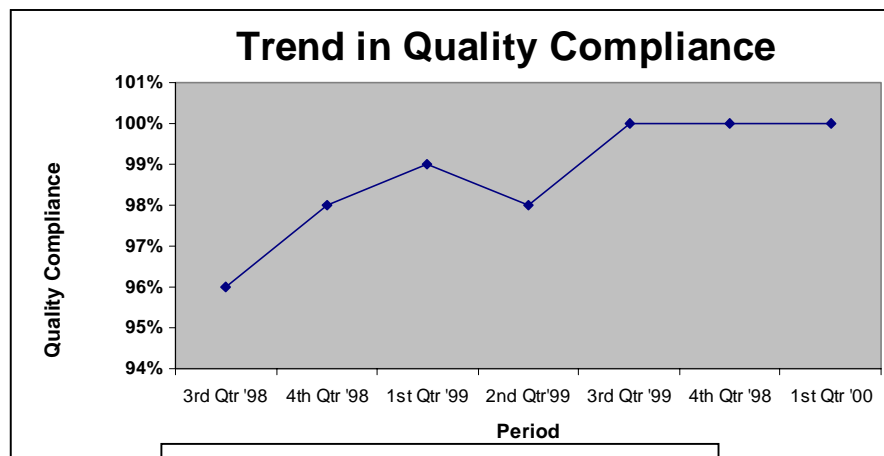
Based on the recommended actions from FMEA, several process improvements were introduced in the phases - Project Study, Execution and Delivery. These improvements include developing process control and error proofing tools amongst others. Figure 5-7 shows some of the improvements carried out in different phases.

In addition to this, a customer feedback form was introduced. The various quality attributes of the

deliverables are rated by the customer on a 1 to 5 scale. Causal analysis is carried out by teams when the rating is below 4 and preventive actions is initiated.

### 5.5 Control phase

The process improvements that were introduced resulted in the reduction of field errors. The process capability for quality of deliverables improved from 3.48σ to



**Figure 5-7: Trends in quality compliance**

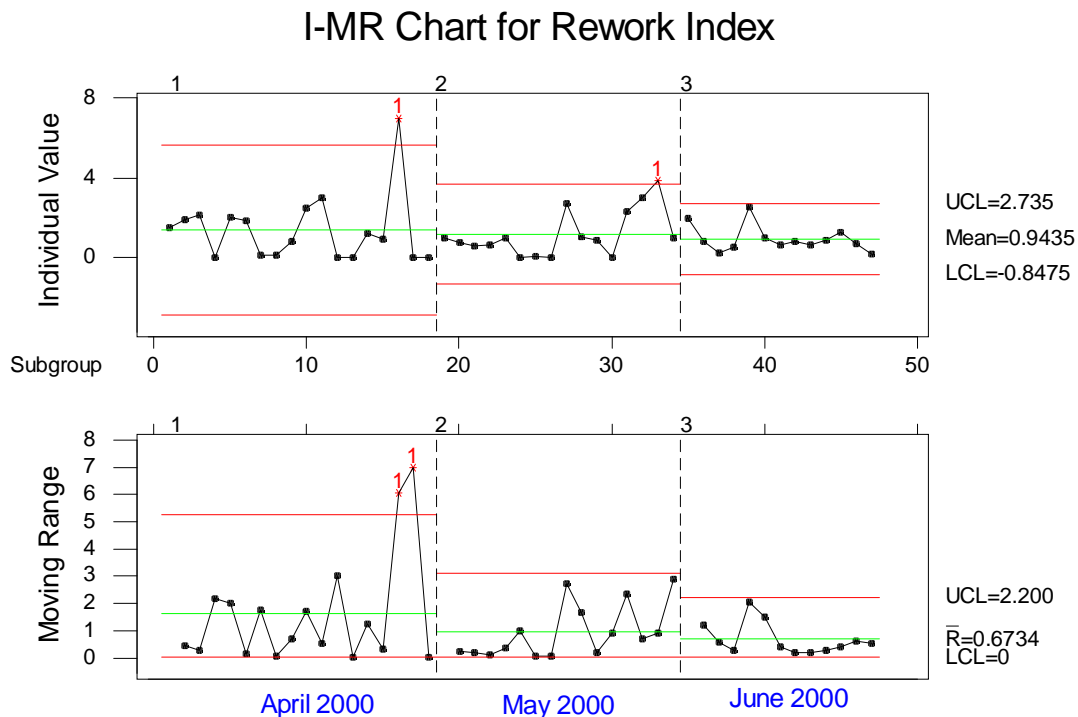
3.98 $\sigma$  in the long-term and from 4.98 $\sigma$  to 5.48 $\sigma$  in the short-term by the end of 1998, and the DPMO reduced from 253 to 34. This trend continued in 1999 and 2000, resulting in the improved trend in the quality compliance as shown in Figure 5-8. The best practices and lessons learnt in this Six Sigma project for engineering design were applied in other project teams and other types of projects.

Since the field errors reduced and the process capability for quality deliverables increased to more than five sigma, the emphasis shifted to improvement of in-process quality. This is to be achieved through reduction of in-process quality cost as explained below.

The project life cycle has a phase for Quality Assurance (QA). As a continuous improvement

initiative, Green Belt projects have been initiated in different project teams, to reduce the rework cost after QA. These Green Belt projects used the results of the Cause and Effect, and FMEA of the Six Sigma project on Quality Compliance.

A number of Defect Prevention practices were identified in these GB projects and were built into the processes of the project life cycle. To measure the quality cost, a metric called "rework" index was used. This metric is calculated as percentage project effort spent in rework. Control charts (I-MR) were drawn to track the process level (process characteristic within projects) and process variation (process characteristic between projects) simultaneously, and also to detect the presence of special causes.



**Figure 5-8 I-MR chart for rework index**

Figure 5-9 shows the Control charts drawn over a period of time for rework index for one of the project teams. The assignable causes for variations from the target values were analyzed, and corrective actions were initiated to remove the causes and to prevent them from occurring again. From the control charts, it is evident that the process improvement initiatives have been effective in reducing the rework index. This is indicated

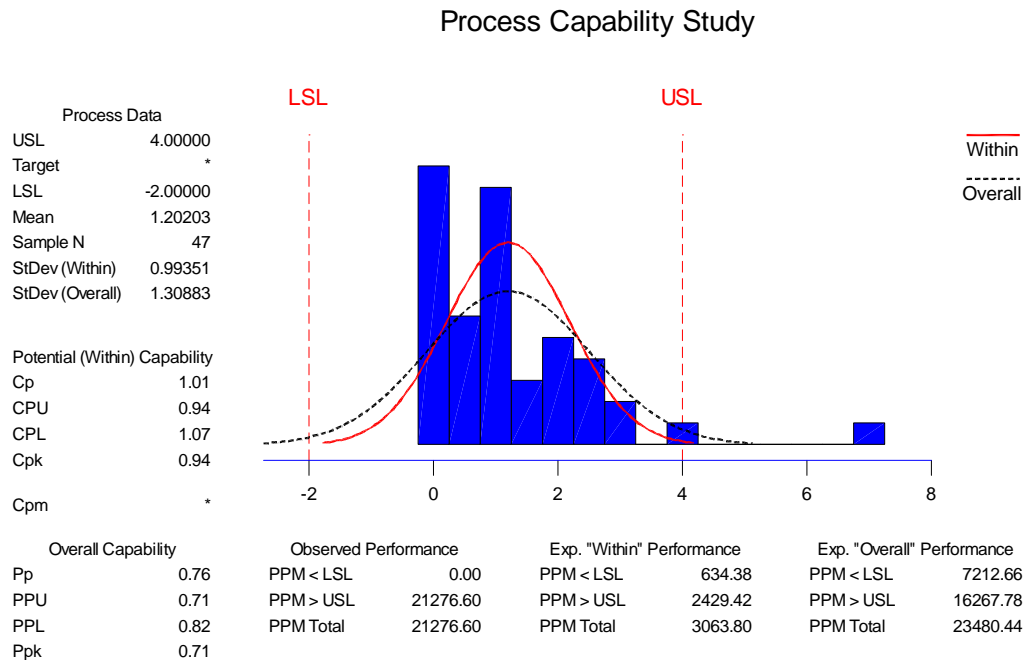
by the converging control limits in the individual's chart and the reduction in process variation as seen in the moving range chart.

Using these values, process capability studies are also undertaken. Figure 5-10 shows the process capability study for rework index in one of the project teams. This study can be used to assess whether the process is centered on the target and whether it is



capable of consistently meeting process specifications. For the metric — rework index, the specification limits were set at 4% to -2% of the project effort as rework

after QA. As seen from the chart, the expected overall performance has a DPMO of 23480, which is equal to  $3.47\sigma$ .



**Figure 5-9 Process capability study**

## 6. Conclusion

The thrust on Six Sigma Quality has helped in creating and sustaining customer focus in the TCS — GEDC, leading to improved customer satisfaction as indicated in the feedback from the customer. At the same time, active participation of the team members from all levels in the Six Sigma projects has evolved a culture of effective and creative team work.

The goal is to achieve Six Sigma level not only in product quality, which is currently at  $5.85\sigma$ , but also in the other client specified metrics of on-time delivery and estimate compliance. To achieve this goal, TCS — GEDC plans to have about 60 Six Sigma projects completed by the second quarter of 2001.

## 7. References

[1] Paulk M, Weber C, Curtis B, Chrissis M.B. (1995) *The Capability Maturity Model: Guidelines for*

*Improving the Software Process.* Addison Wesley Publishing Company, Reading, MA.

[2] Forrest W. Breyfogle *Implementing Six Sigma: Smarter Solutions Using Statistical Methods :*

[3].  $6\sigma$  OJT Six Sigma Application – GEPS Playbook, GE Power Systems

## 8. Author information

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