The Evolution of Quality Processes at Tata Consultancy Services

This article describes how the quality processes have evolved at Tata Consultancy Services and how the framework of ISO 9000 and then the Software Capability Maturity Model have catalyzed the evolution.

Gargi Keeni, *Tata Consultancy Services*

Tata Consultancy Services (www.tcs.com) was established in 1968 as part of the Tata group of companies. TCS has grown to be the largest software and management consultancy organization in southern Asia, with over 14,000 professionals under the leadership of Faqir Chand Kohli. It initiated its quality journey in the '70s as part of its strategy to become a global top-10 software company. Over the past decade, distinct changes have occurred in how TCS disseminates its quality policy internally to achieve enterprise-wide involvement. This article describes the path traversed and the lessons learned.

As you will see, the institutionalization of processes takes time. Although TCS embarked on its CMM journey in 1996 and achieved Level 4 by 1998, the stage for that was set much earlier during ISO 9000 certification. The same was true for ISO 9000 certification. The initial culture change of moving toward systematic process is comparatively difficult. Once that is streamlined, building further improvements on it is relatively smooth.

Background

TCS first implemented quality control procedures in the early '70s—when the projects executed were mainly bureau jobs. To ensure design quality, TCS introduced structured systems analysis and design processes in 1982 and then guidelines for software life-cycle activities. To support this design method and data modeling, the company then started using CASE tools developed at the Tata Research Design and Development Center. It introduced procedures for milestone reviews from 1983 to 1984. The shift from quality control to quality as-

Table 1

Quality Certifications at Tata Consultancy Services

Quality resource	Qualified people
Candidate People-CMM lead assessors	1
Software Eng. Inst.-authorized Software-CMM lead assessors	3
Internally trained CMM assessors	77
Tata Business Excellence Model external examiners	5
TBEM internal examiners	20
Certified Quality Analysts (certified by the US Quality Auditing Inst.)	678
Quality auditors	Over 300

surance was gradual, emphasizing conformance to the standards and guidelines for life-cycle activities. TCS achieved this through the training of new employees.

However, lack of information sharing, lack of standardization across similar projects, and difficulty in learning from past projects caused complications. Problems in one project would recur in others. Solutions would get reinvented again and again, resulting in lost time and effort and in schedule overruns.

To address these issues, TCS instituted quality assurance groups. By the late '80s, QAGs were active in all major TCS branches. They assessed software quality, ensuring that software development conformed to the processes, standards, and guidelines in the software development life cycle. They also collected feedback from the project teams, for initiating process improvement and for piloting and deploying software engineering practices across the organization.

During the '80s, TCS formed a software estimation group, which drafted estimation procedures and reviewed the estimates prepared by the projects. This group also tracked the estimated versus the actual figures and revised the guidelines as required.

TCS started documenting its quality management system in the early '90s. The QMS is a repository of processes, procedures, standards, and guidelines for helping project teams execute projects of various kinds. It was developed by a group of professionals and embodies more than 10,000 person-years of project experience and expertise.

To sustain and improve process awareness, TCS reoriented the mission of its training programs, which were established in 1978. Besides imparting technical skills, the training programs began disseminating information on quality processes, procedures, and standards. Today, 60% of the curriculum in the initial training program teaches software engineering processes. The continuing education program focuses on updating professionals' knowledge with new skills and emerging technologies.

TCS continually evaluates itself against a set of quality models. Table 1 summarizes the current qualifications of TCS staff for implementing and evaluating quality practices.

Aligning with the ISO 9000 Quality Standards

In 1992, TCS decided to adopt ISO 9000 as a quality norm, triggering the formal documentation of the QMS. This was the first time that TCS compared itself against a quality framework. Although TCS had adopted parts of the IEEE standards for software processes, complying with ISO 9000 standards required more effort, including a full-fledged audit mechanism inside TCS.

The next step was to identify the functions that had to be reinforced with respect to ISO 9000. This was relatively easy because QAGs were already active in all major TCS centers. In this exercise, TCS strengthened processes such as

- environment and configuration management,
- software metrics,
- project tracking,
- contract review, and
- document control.

TCS had to organize extensive training for the project leaders in each of these areas. For example, because TCS had recently introduced document control procedures, the QAGs had to facilitate the project team to understand and follow them rigorously. Obtaining ISO 9000 certification for all the major TCS centers took two years. The first two centers were certified in January 1994.

Institutionalization of Audits and Project Management Reviews

Initially, each center's QAG handled QMS training. After training the existing staff, the QAG handed over the responsibility to the training group, which introduced the QMS as part of the curriculum for new employees. TCS initiated quarterly audit cycles to identify instances of nonconformance and to track the deployment of this institutionalization. At the end of each audit cycle, the project leaders, group leaders, and center manager held an audit-closing meeting, where they discussed a causal analysis of nonconformances. Suggestions for corrective and preventive action were solicited during these meetings. Strong management commitment was a key factor in sustaining this institutionalization. TCS initiated project management reviews to monitor the institutionalization.

Activity-Based Costing

TCS introduced activity-based costing along with ISO 9000 to steer the software metrics program. The metrics guidelines, defined in 1993, were meant to achieve quality objectives by monitoring effort, defect, schedule, and size.

The activity-based costing system provides a tool for efficient project management. Any activities that are essential for executing project tasks right the first time are tagged as *value-adding effort*. Others, such as idle time and rework, are tagged as *non-value-adding effort* and tracked so that TCS can reduce them, thereby improving productivity and reducing cost. For instance, idle time could be due to unavailability of resources or the communication link being down. The concept of *cost drivers* as the reason for performing an activity is central to this approach. Value-adding cost drivers, such as the number of components for design document creation, the number of test cases required for testing, and the number and complexity of program specifications for coding, are *normal cost drivers*. Activities that create non-value-adding cost drivers, such as client-induced change in scope or delay in acceptance, are *not-normal cost drivers*. Aggregating costs for non-value-adding cost drivers helps the project team both identify wasted effort as the project progresses and take early corrective actions.[1]

In the early '90s, TCS found that even successful projects had rework as high as 34%. So, the metrics program includes rework to highlight opportunities for productivity gains. Figure 1 shows how rework decreased from 1996 to 1999.

Integrated Project Management System

Implementing these quality initiatives involved managing change that was characterized by

- a reluctance to document,
- a perceived increase in paper work, and
- additional effort required for metrics collection, which was known to be not immediately beneficial to the project at hand.

Lapses in metrics collection and inadequate project planning resulted in large numbers of nonconformances, as Figure 2 shows.[2] Plans and metrics were not updated, because of the high volume of manual work involved, even on successful projects. At the organization level, it was difficult to retain lessons learned from past experiences and make them available for the success of future projects.

To address these issues, TCS organized

The activity-based costing system provides a tool for efficient project management.

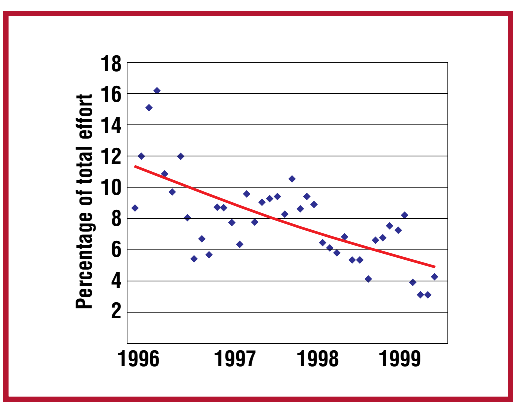


Figure 1. The reduction in rework. Each data point indicates the rework effort as a percentage of the total effort, for one project.

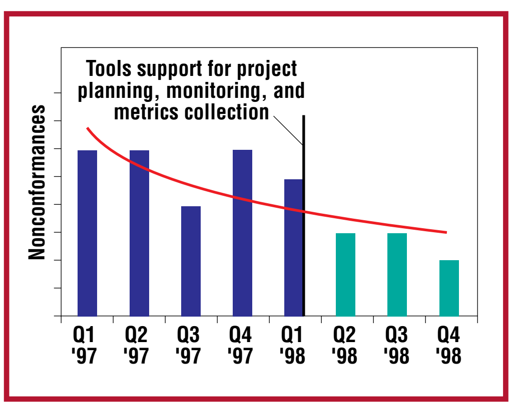


Figure 2. Nonconformances due to lapses in metrics collection. The curve shows the trend line.

This learning process triggered the creation of intranets aimed at sharing business and process knowledge, lessons learned, and best practices.

training and workshops. Once the participants accepted the basic merits of process institutionalization, the company solicited their suggestions. This was followed by meetings where project leaders shared their experiences and explained to project members the benefits of metrics collection and causal analysis. TCS developed tools such as the integrated project management system to assist and simplify the ongoing collection, tabulation, and analysis of various metrics, eliminating the need to manually enter data and update the project plan.

TCS began developing the integrated project management system in 1993, after documenting the QMS. The system consolidated the experience TCS gained using previous in-house tools for defect and effort logging, and other project management tools. Although these tools provided the first step toward automation, they were not integrated and exhibited three main problems.

First, the planned effort and schedules in the project management tools were independent of the actual effort and schedules updated through time sheet entries in the costing tool. This hindered meaningful data analysis and interpretation.

Second, the time sheet entry itself was sometimes erroneous. For example, documentation of project requirements should have been entered under the requirement analysis phase but was sometimes booked under overall documentation. This made drawing meaningful conclusions from the data difficult.

Third, a group shared its planning information with other groups only at the project's start and not after subsequent updates. This caused planning difficulties and crises for the other groups.

TCS reduced the burden of micromanagement on the project leaders by incorporating the entire QMS in the integrated project management system. This built-in workflow, based on the operational process defined during the planning phase, provided the framework to guide the team through the various software development stages.

Adopting the Software Capability Maturity Model

In 1996 TCS decided to adopt the Carnegie Mellon University Software Engineering Institute's Software Capability Maturity Model.[3] Achieving ISO 9000 certification had provided TCS with most practices required to achieve CMM Level 3. The next step was to incorporate statistical techniques into the metrics program to control quality. Measures of effort slippage, defect density, and schedule slippage helped TCS improve estimation and planning, service levels, and productivity.

The Seepz Pilot

For deploying processes for statistical process control and data analysis, TCS had two options:

- an enterprise-wide deployment program similar to the one implemented for ISO 9000, or
- a localized approach concentrating on a development center as the pilot.

Considering the organization's spread and size, TCS chose the localized approach to reduce the learning curve and turnaround time.

TCS decided that the first center assessed for CMM would be the one at the Santacruz Electronics Exports Processing Zone, in Mumbai. With a staff of over 1,000 professionals, TCS-Seepz consists of six offshore development centers that service some of TCS's largest overseas clients. TCS-Seepz manages staffing, infrastructure support, and quality assurance for over 100 projects, ranging from one person to more than 100 persons, with schedules of three months to over two years. The projects operate in various environments, ranging from mainframes to open systems, and include development, conversion, and maintenance.

The first step was to form a *software engineering process group*, which conducted a detailed benchmarking of the existing QMS with Software CMM. The objective of achieving CMM Level 4 at TCS-Seepz required enhancing the metrics program through statistical process control. The SEPG enhanced the QMS with policies, processes, procedures, standards, and guidelines to implement the key practices of two key CMM process areas: quantitative process management and software quality management.

At that point, the project teams and the SEPG were collecting the size, schedule, effort, and defect metrics, but the analysis was

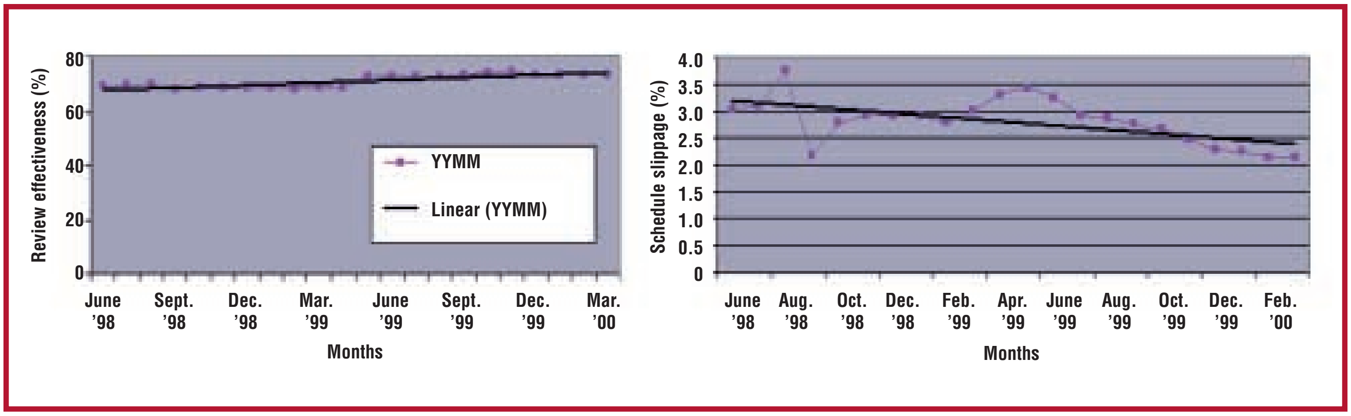


Figure 3. Improvements at TCS-Seepz in (a) review effectiveness and (b) schedule slippage. The solid black lines indicate the linear fit.

limited to the project level. The SEPG enhance metrics program in mid 1997 to define goals, metrics, and analyses at the center level. Using these measures, the SEPG created control charts to monitor schedule slippage, in-process defects per component, and maintenance field errors. Analysis of outliers provided valuable inputs to the center for both lessons learned and best practices. An outlier below the lower control limit might lead to identification of best practices. For example, automation used by a particular team might reduce the cycle time. This can be institutionalized in similar kinds of projects.

The project teams and the SEPG used run charts to track review effectiveness, measured as the percentage of defects detected in peer reviews before testing. Project leaders used control charts of code walk-throughs to determine the reason for outliers and improve their walk-through checklists.[4] Figure 3a displays the improvement over time in review effectiveness.

Analysis of special causes of problems in estimating and scheduling technology projects led to guidelines for executing new projects. One benefit was reduced schedule slippage (see Figure 3b), which resulted from better control over the project scope and improved change management.

One major challenge was to train the large number of new entrants and a significant number of experienced professionals joining TCS-Seepz over a relatively short time. TCS instituted this training to respond to the ever-growing business and to bridge the gap created by persons leaving TCS-Seepz for other TCS assignments. The company organized this training as a part of its continuing education program.

TCS-Seepz was assessed at CMM Level 4 in July 1998.

Two More Pilots

In 1997, TCS's relationship with US West and Hewlett-Packard culminated in the setting up of two offshore development centers at Chennai, India. At that time, TCS proposed the deployment of CMM at these facilities using the tried and tested processes from TCS-Seepz. They set a stretched target of CMM Level 5.

Gap analysis of the Level 5 key process areas—defect prevention, technology change management, and process change management—showed that the centers were, to a certain extent, following the basic practices of defect logging, causal analysis of defects, and identifying the corrective measures. However, these centers required additional processes for analyzing common causes of defects to systematically eliminate these causes in the future. Senior management adopted stringent measures to address technology and process change management, which included systematic cost–benefit analysis relating to business goals. Relating the CMM movement to the Tata Business Excellence Model (which is patterned after the US Malcolm Baldridge National Quality Award) in this manner helped.

Knowledge sharing. The offshore-development-centers model pioneered by TCS changed the way project teams viewed themselves. They developed a strong sense of identity as part of a cohesive group delivering quality services to a specific client. Project teams found that they needed to understand the work on related projects at their offshore development center. This cohesiveness increased the spread of business knowledge across teams, which in turn enhanced each project's capability to handle system requirements.

This learning process triggered the cre-

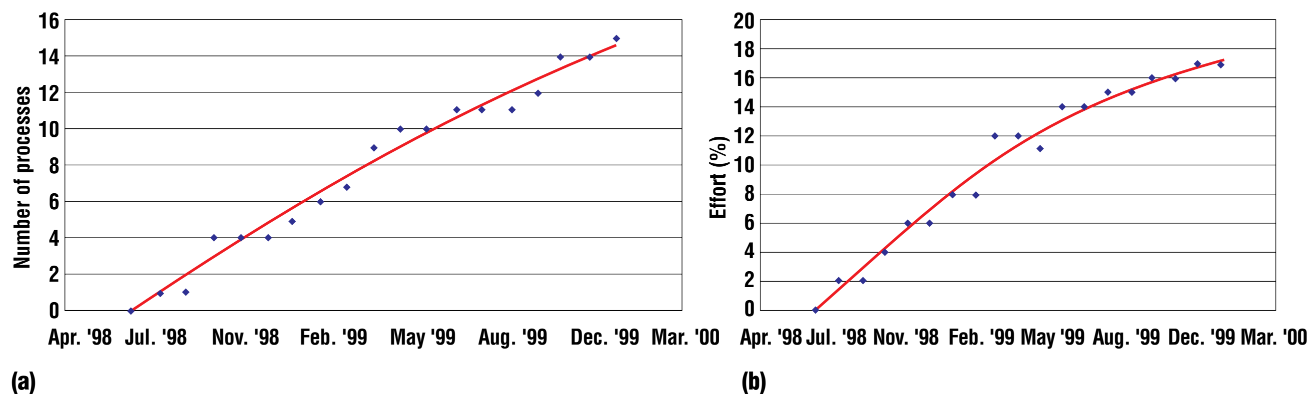


Figure 4. (a) The increase in process automation and (b) the corresponding increase in effort saved at the Hewlett-Packard pilot site. The solid red curves indicate the trend lines.

ation of intranets at the centers, aimed at sharing business and process knowledge, lessons learned, and best practices. The intranets were the starting point for discussion forums and suggestion boxes. The center manager introduced a "best suggestion of the week" program and informed everyone at the center. In weekly executive meetings, project managers, project leaders, and the center manager discussed the process-related suggestions received during the week and selected the best one. They invited that suggestion's author to the next meeting and gave him or her a gift certificate for books as a token of appreciation. The suggestion and the author's photo were published on that center's intranet. This motivated people to make more suggestions.

In February 1999, the audits started verifying the updating of lessons learned; this has produced a sustained increase in additions to the lessons-learned database. Any person in the organization may post a lesson learned in the lessons-learned database; this provides a source for suggestions. The main incentive for posting a lesson learned is the professional satisfaction of sharing knowledge.

Mentors and process primes. The size of these centers (fewer than 500 people each) allowed experimentation with *process primes* and *technical mentors*. A process prime is a member of a project team who acts as a link between the process owner and the project team. Individual process primes might be assigned to each CMM key process area, or the primes might have overlapping responsibilities. Besides their regular project responsibilities, process primes from all the projects met periodically with the process owners (referred to at TCS-Seepz as CMM coordinators) to discuss implementation issues, improvements, and suggestions. The primes subsequently communicated the status of different process improvement initiatives in their project meetings, and they deployed and monitored the progress of these initiatives in their project. Process primes provided the focal point in each project for coordinating process improvements initiated by the process owners. This created improvement synergy across the center.

A technical mentor is an experienced member of the project team—occasionally the project leader on small projects. One technical mentor might be responsible for more than one new entrant, but each technical mentor would not handle more than three new entrants at one time.

Process automation. As processes were increasingly automated, TCS needed to understand the implications of this automation and measure its benefits. So, the company monitored the amount of effort that process automation saved. Figure 4 reflects the impact of process automation at the Hewlett-Packard pilot site. TCS introduced the Projects, Resources, Operations, Metrics, Planning & Tracking (Prompt) system in steps. At each step, the company measured the reduction in overall effort for managing the process. Initially, the fundamental processes such as project planning and tracking, risk tracking and monitoring, defect logging, audit management, and effort logging were gradually automated. Use of higher-level tools such as statistical process control and suggestion systems followed this automation.

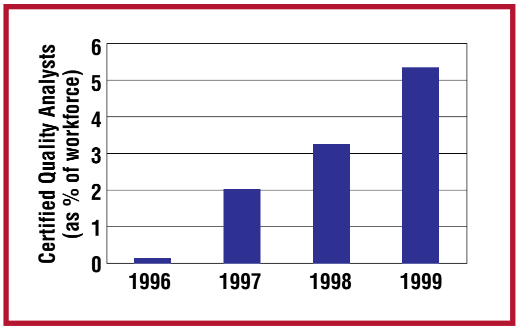


Figure 5. The increase in Certified Quality Analysts as a percent of the workforce.

The payoff. The TCS–US West and TCS–Hewlett-Packard Centers were assessed at CMM Level 5 in April and July 1999, two years after they were established. At these centers, average review efficiency increased by 10%, reducing rework effort by 5%. The average schedule slippage decreased to 0%, and the effort ratio was between 0.9 and 1.1.

Consolidation of the CMM Experience

By mid 1998, TCS drafted a plan for extending the CMM movement to its remaining development centers. The plan detailed several measures to implement the lessons learned from the pilot centers. One was to merge the enhanced pilot-site QMSs into the organization-wide QMS. Changes to the integrated project management system were also necessary. Besides a QAG and an audit group, TCS placed an SEPG at each center to spearhead the process improvement program. The deployment was entrusted to the QAGs, whose capabilities were enhanced by training in CMM and the related processes.

Institutionalizing the enhanced QMS across the diverse operations of 17 development centers in India was a major challenge. One step was to start bimonthly meetings of each center's SEPG. These meetings provide a platform for the groups to share instances of best practices and inculcate a sense of ownership. Another significant step was the launch of the TCS corporate intranet, which deployed the process assets library. This provided an excellent medium for sharing information and knowledge.

The centers at Sholinganallur (Chennai), Seepz, Calcutta, Bangalore, Lucknow, and Hyderabad have been assessed at Level 5. The Ahmedabad center was assessed at Level 4.

Organization-Wide Deployment Strategies

The keys to deploying Software CMM throughout the organization were staff involvement and TCS's Certified Quality Analyst initiative.

Staff involvement. The major hurdle faced in implementing new or modified processes was their deployment in projects. Because project leads were already burdened with the overall project execution, including client interactions, they could not devote enough time for process improvement initiatives. To circumvent this problem, TCS assigned process primes to help the center-wide process owners develop the deployment strategy. One criterion for selecting the process owners is their wide acceptability in the organization. The process owners are actively involved in defining the processes and monitoring deployment progress. They meet periodically to discuss the status of deployment of new initiatives, review the pilot results, and identify new areas for improvement. This modified deployment strategy has led to the involvement of a wider cross-section of employees and has resulted in higher buy-in from projects. Ownership of process improvement permeates the organization; it is not restricted to a select few.

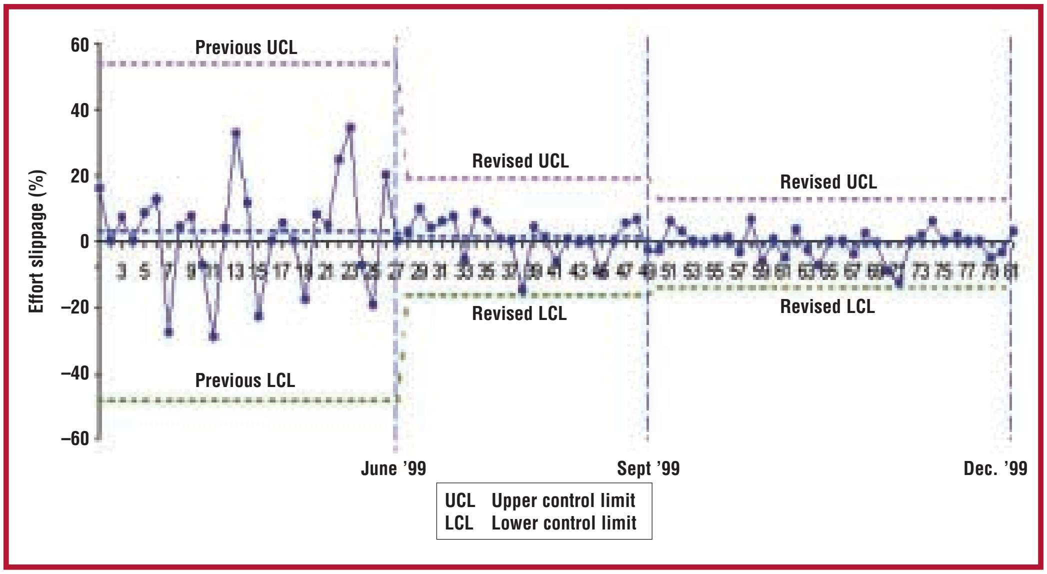
The Certified Quality Analyst initiative. Experience from TCS-Seepz revealed that sustaining quality-related activities requires constantly informing staff about process improvement initiatives and facilitating their active participation. To create champions of quality initiatives who would practice statistical techniques, TCS reinforced an initiative started in 1996 to encourage its professionals to attain the Certified Quality Analyst certification from the US Quality Assurance Institute. The target is to have 10% of the total staff certified at the end of 2000. Figure 5 displays the growth of Certified Quality Analysts as a percent of the total workforce from 1996 through 1999.

Results and Benefits

TCS's CMM initiative has benefited both the company and its customers.

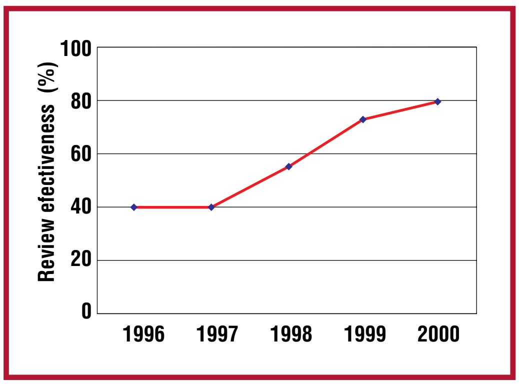
Effort estimation. Because effort estimation is important to project management, TCS brought effort slippage under quantitative control, as Figure 6 shows for the Calcutta center. The first quantitative computation of effort slippage was done for projects through June 1999. Although this process was under statistical control, the process variation was quite high—approximately ±50%. TCS attributed this spread to incor-

Figure 6. Continuous improvement in estimation accuracy for the Calcutta center. The *x*-axis indicates the instance numbers.



rect effort estimates resulting from inadequate estimation guidelines. So, the company enhanced estimation guidelines and mandated tool-based estimation. Slippage analysis during the next quarter (July through September 1999) showed a marked reduction of process control limits to approximately ±20%. At this point, further analysis of the slippage data indicated that rework due to defects consumed substantial additional effort. The defect prevention program focused on reducing rework. This led to further-reduced process spread by the end of December 1999, with stability limits of approximately ±15%.

Figure 7. The improvement in review effectiveness.



Review effectiveness. The overall review effectiveness has been increasing (see Figure 7), which substantiates early error detection. Higher review effectiveness ensures that less effort is spent on detecting and

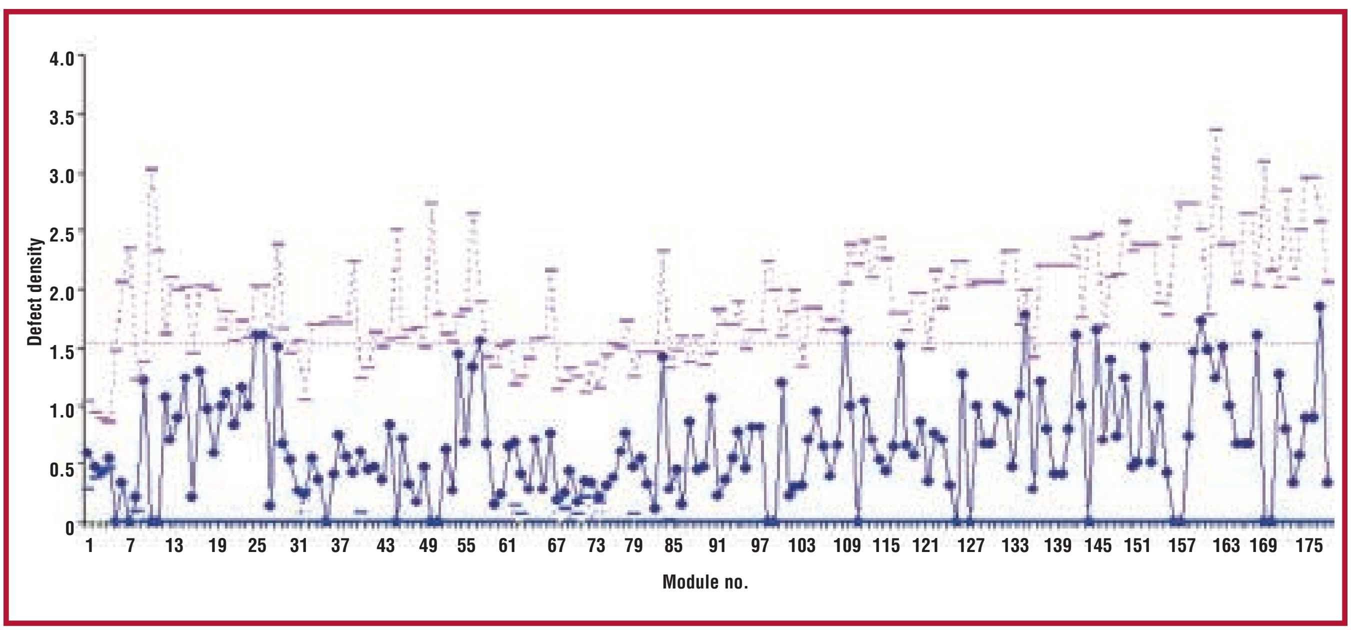


Figure 8. A U-chart for module defect density.

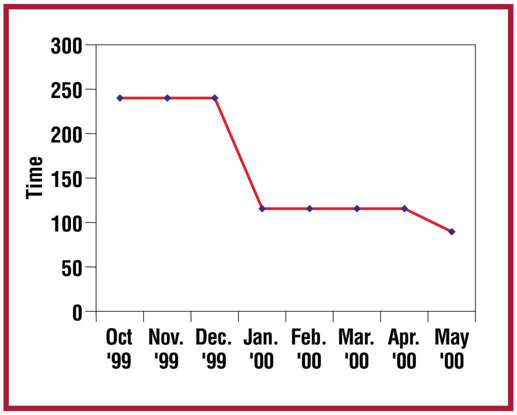


Figure 9. An example of service-level-agreement tracking for troubleshooting operating system problems.

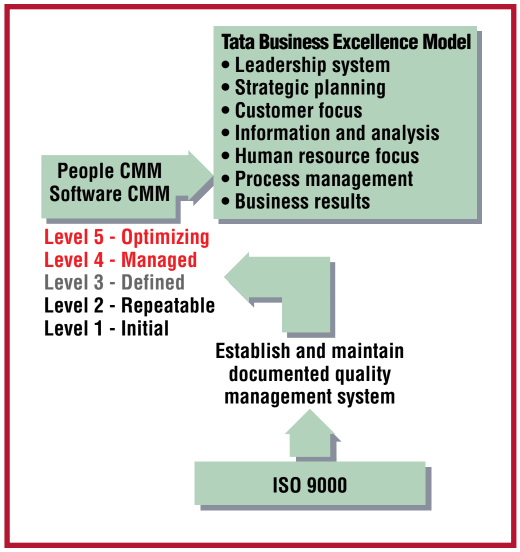


Figure 10. The context of the CMM initiatives with regard to the Tata Business Excellence Model (patterned after the US Malcolm Baldridge National Quality Award).

correcting defects, thereby reducing the overall project effort.

Product quality. To ensure that TCS delivers quality products, it tracks defect density for each delivered module to ensure this measure is under statistical control. Figure 8 presents a U-chart for defect densities used to ascertain the stability of review and testing processes. The upper control limits appear jagged because they are adjusted for the module's size.

Customer benefits. The process improvement initiatives produced significant customer benefits.[5] The deployment of project management tools decreased the effort required for project planning and tracking, reducing by 5% the effort required for project management. As project-estimating models improved, the effort of executing a change request decreased by 23.64%, while the capacity to handle work increased to 2.5 times the original baseline. As TCS closely tracked these efforts, including idle time, and shared the results with the customers, the company could project the patterns of the idle time, thereby putting in measures to reduce it and get better throughput. Improved induction training for new team members and better project documentation helped reduce by 70% the time to close a trouble ticket.

Benefits to the organization. The culture of managing in quantitative terms has spread to support groups. It has encouraged a competitive environment among these groups, who are proactively tracking their service level agreements with internal customers. The groups use statistical techniques to analyze the problems or issues to improve their performance against service level agreements. Figure 9 shows an example of service-level-agreement tracking for troubleshooting operating system problems.

TCS has continued its pursuit of excellence by further aligning its efforts with the Tata Business Excellence Model to achieve overall organizational effectiveness by focusing on customer-driven quality and nurturing quality values in the operational domain. Software CMM deployment at the delivery centers has set the stage for adopting personal software process[6] and team software process.[7–9] This will sustain software process improvement, better quality through systematic evaluation, and enhanced organizational learning and sharing. To align the human resource processes with the company strategy, TCS has started benchmarking its human resource processes against People CMM.[10] Figure 10 displays the relationships between the various quality models that TCS has used to guide its quality journey.

Learning from experience will continue. TCS will analyze processes data, information, and experiences to obtain better insight, for strengthening evaluation, decision-making, operational improvement, and the culture of management by facts, a core value of the Tata Business Excellence Model.

Acknowledgments

I thank my colleagues and the software engineering process groups and quality assurance groups of all the Tata development centers for their valuable input. I also thank Bill Curtis, the guest editor of the CMM focus in this issue, for his valuable assistance in improving this article's presentation.

References

1. S. Mahalingam, B.V. Balachandran, and F.C. Kohli, "Activity-Based Management for Systems Consulting Industry," *J. Cost Management*, Vol. 3, No. 3, May/June 1999, pp. 4–15.
2. G. Keeni, "Measures and Continuous Process Improvement," *Proc. 1999 Indian Software Eng. Process Group Conf.* (SEPG 1999) (CD-ROM), Quality Assurance Inst. India, New Delhi, India, 1999.
3. M. Paulk et al., *The Capability Maturity Model: Guidelines for Improving the Software Process*, Addison-Wesley, Reading, Mass, 1995.
4. R. Radice, R. Sokhi, and P. Suresh, "Journey to Level 4: TCS Seepz Software Process Improvement," *Proc. European Software Eng. Process Group Conf.* (CD-ROM), European Software Process Improvement Foundation, Milton Keynes, UK, 1999.
5. S. Ramadorai, "Process Orientation: The Only Option," *Proc. 2000 Software Eng. Process Group Conf.* (CD-ROM), Software Eng. Inst., Carnegie Mellon Univ., Pittsburgh, 2000.
6. W.S. Humphrey, "Using a Defined and Measured Personal Software Process," *IEEE Software*, Vol. 13, No. 3, May 1996, pp. 77–88.
7. W.S. Humphrey, "Three Dimensions of Process Improvement, Part I: Process Maturity," *CrossTalk: J. Defense Software Eng.*, Feb. 1998, pp. 14–17.
8. W.S. Humphrey, "Three Dimensions of Process Improvement, Part II: The Personal Process," *CrossTalk: J. Defense Software Eng.*, Mar. 1998, pp. 13–15.
9. W.S. Humphrey, "Three Dimensions of Process Improvement, Part III: The Team Process," *CrossTalk: J. Defense Software Eng.*, Apr. 1998, pp. 14–17.
10. B. Curtis, W.E. Hefley, and S. Miller, *People Capability Maturity Model*, Tech. Report CMU/SEI-95-MM-02, Software Eng. Inst., Carnegie Mellon Univ., Pittsburgh, 1995; www.sei.cmu.edu/publications/documents/95.reports/95.mm.002.html.

About the Author

Gargi Keeni is the corporate quality head at Tata Consultancy Services, responsible for managing organization-wide process improvement. A Certified Quality Analyst and lead assessor for Software CMM, she has extensive experience in software project management, software tools development, managing training activities, managing human resource allocation, and managing quality processes implementation. She has conducted several courses and workshops on quality management, Software CMM, People CMM, ISO 9000, and the JRD Quality Value Award (now the Tata Business Excellence Model; both are based on the Malcolm Baldridge National Quality Award criteria adapted by the Tata Group of companies). A qualified internal examiner for the JRD-Quality Value award, she is also a Candidate Lead Assessor for the People CMM. After completing her master's in nuclear physics at Calcutta University, she received her PhD in nuclear physics from Tohoku University of Japan. She is a member of the Computer Society of India and the IEEE. Contact her at Tata Consultancy Services, AI Bldg. 11th Floor, Nariman Point, Mumbai 400021, India; gkeeni@mumbai.tcs.co.in.