Total Quality Management in the Switching Systems Business Unit

Ronald G. Basinger
Michael J. DiMario
Thomas C. Pingel
Michael J. Urban

AT&T's Quality Policy is based on two fundamental axioms—unqualified customer satisfaction and continuous quality improvement. The Switching Systems Business Unit implements its quality policy through Total Quality Management (TQM), which ensures improvement in those areas most important to our customers. This paper includes:

- An overview of the TQM system, identifying eight system elements and focusing on policy deployment and process management,
- How TQM produces products and services that exceed customers' expectations, and
- How the Malcolm Baldrige criteria and ISO 9000 standards support continuous improvement.

Following are two examples of process quality improvements, root cause analysis and product quality assessment. The paper concludes with a look at the evolving concept of customer value added.

Introduction

AT&T's Quality Policy is based on two fundamental axioms:

- Unqualified customer satisfaction, and
- Continuous quality improvement.

In the Switching Systems Business Unit (SSBU), that policy is implemented through a customer-driven approach, Total Quality Management (TQM), which ensures that the SSBU targets for improvement those areas that are most important to its customers. For example, the SSBU's primary customers, telecommunications service providers, have made it clear that switch quality and reliability are their highest priorities. Thus, the SSBU's goal is to provide the highest quality and most reliable switch in the world. With an average downtime of about one minute per switch per year, confirmed by recent FCC data,[1] the 5ESS® switch's availability is three times better than the customers' requirement.

This paper describes how the SSBU's quality management has grown directly from its emphasis on customer satisfaction. It begins with an overall description of the SSBU's implementation of Total Quality Management, with emphasis on those elements that identify and direct quality improvement efforts. Then, two examples are presented of process quality improvements driven by the customers' highest priority, switch reliability. Both examples are of automated quality information systems that facilitate the intense use of data in the improvement process. The first example is a tiered implementation of root cause analysis (RCA), a technique for removing and preventing defects. The second, product quality assessment (PQA), is a model for assessing and predicting the number of defects in large software products at various points in the development cycle.

This paper concludes with a look beyond the traditional concepts of customer satisfaction to the evolving concept of customer value added (CVA). This technique not only helps identify customers' most important priorities, but compares the SSBU's performance in those key areas to the competition. In doing so, the SSBU gains a powerful capability to predict market performance, which can influence strategic direction, as well as identify areas for product and process improvement.

Panel 1. Acronyms Used in This Paper
CVA — Customer value added
FCC — Federal Communications Commission
ISO — International Organization for Standardization
PMT — Process management team
PQA — Product quality assessment
PQMI — Process quality management and improvement
QIP — Quality improvement project
QIT — Quality improvement team
RCA — Root cause analysis
SSBU — Switching Systems Business Unit
TQM — Total Quality Management

The scope of this paper is primarily the *product development arena* and does not directly address other areas, such as manufacturing. However, Total Quality Management in the SSBU is coordinated through all aspects of the business, and the emphasis on the customer is pervasive.

An Overview of TQM

Total Quality Management is part of the SSBU's strategy to provide the highest quality and premium value of its products and services (See Figure 1). Total quality is characterized by a management approach that is deployed consistently throughout all functions of the organization. The result is operational performance that meets or exceeds the expectations of customers, employees, and shareholders alike.

Total quality in the SSBU is applied to all its hardware- and software-based products, which vary in size and complexity. The customers' requirements are typically characterized by such strict constraints as functionality, response time, and reliability. The larger products, characterized by extensive hardware and software development efforts, include the SSBU's flagship product, the 5ESS switch. Periodic releases of this product can contain several hundred thousand lines of new source code built on a complex, multi-million line source code base.

Traditionally, the SSBU's management approach has had a *project orientation.* A project management organization worked with the development community to formulate and track large, complex development and deployment plans that could include thousands of product milestones. The SSBU then enhanced its management approach to include not only the project management orientation, but also a *process orientation* for managing and improving the *processes* that are used to develop and deploy products. Additionally, market pressures demanded that the SSBU focus on strategic elements of our business, including *performance breakthroughs*, to achieve and sustain market leadership.

The integration of the project and process management approaches, together with the need for a customer-focused, prevention-based management approach to product development (an approach that avoids introducing errors), formed the foundation for the SSBU's total quality management system.

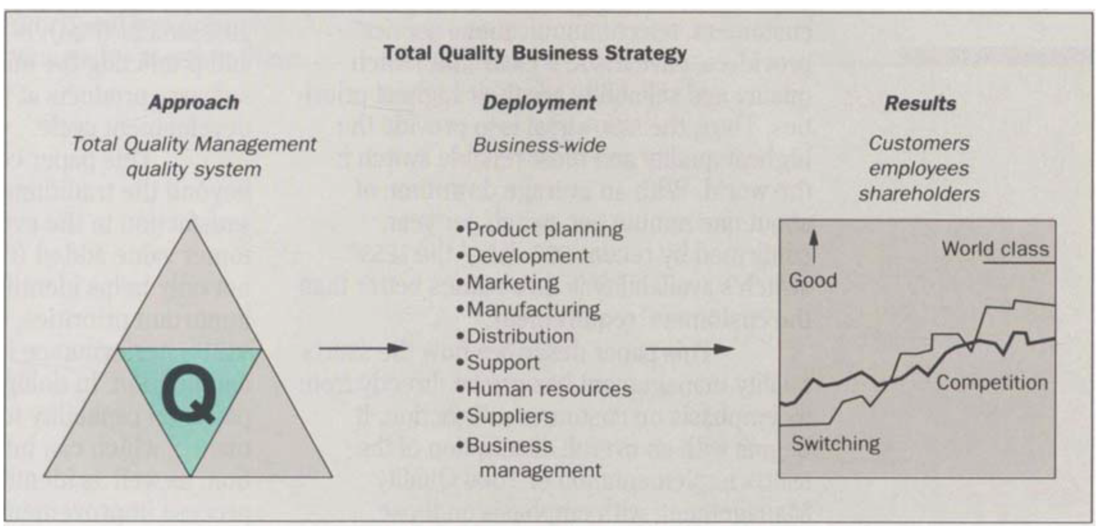

Figure 1. The SSBU's strategy includes Total Quality Management to provide the highest quality and premium value of its products and services. Total quality is deployed business-wide, throughout all functions of the organization. The object is performance that meets or exceeds the expectations of customers, employees, and shareholders.

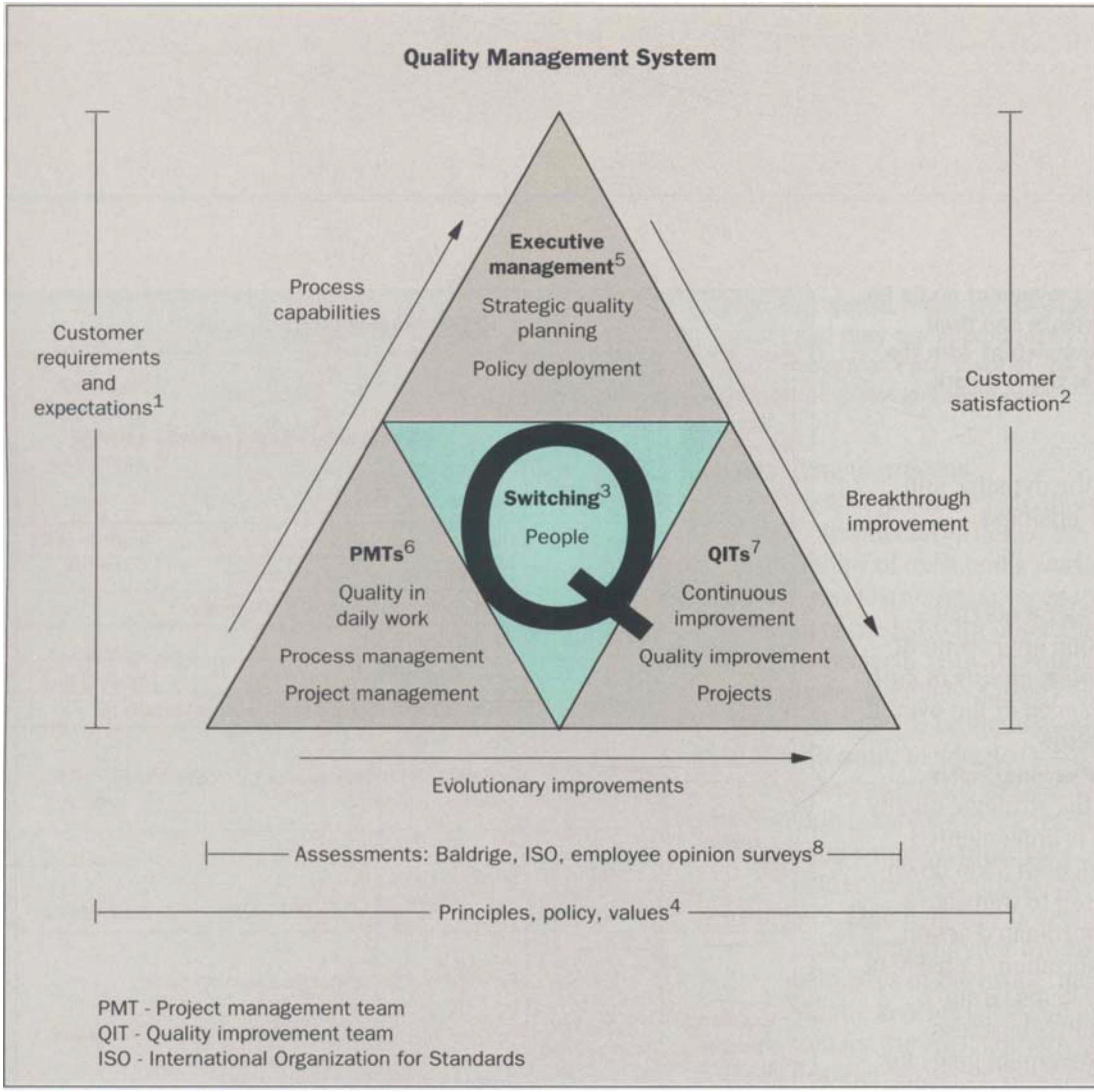

Figure 2. The SSBU's quality management system consists of eight elements that are designed to focus on customer satisfaction. Executive management, project improvement teams, and quality improvement teams each have their areas of responsibility. The result—improved process capabilities, evolutionary improvements, and breakthrough improvements.

Approach to Quality Management. The SSBU's approach to Total Quality Management consists of eight elements (See Figure 2). All elements of the model are designed to focus on the SSBU's customers. Each of the elements is described briefly as follows:

1. Customer Requirements and Expectations: A robust front-end process is used to determine customers' needs and expectations and translate them into internal requirements.

2. Customer Satisfaction: Formal processes are used to gather, analyze, and take action on customers' feedback, to ensure the SSBU is not only providing customer satisfaction, but is exceeding the customers' expectations.

3. People: Career development, performance management, training, and recognition processes support this critical resource. Formal feedback on the work environment and job satisfaction also are solicited annually through an employee opinion survey.

4. Principles, Policies, Values: The SSBU's management system is grounded in the AT&T Quality Policy, Quality Principles, and Common Bond.

5. Strategic Quality Planning: This executive-led process identifies and manages the strategic elements of our business—and the necessary breakthroughs—by establishing and tracking annual and long-term goals.

6. Quality in Daily Work: Project and process management disciplines address the needs of the SSBU's products and work processes. Process management teams (PMTs) focus on the management and evolutionary improvement of everything the SSBU does.

7. Continuous Improvement: Whether supporting a strategic planning goal or working on an improvement opportunity from a process management team, quality improvement teams (QITs) are trained in problem-solving techniques to improve the SSBU's level of performance.

8. Assessments: The SSBU uses internal and external assessments, against such standards as the ISO 9000 Quality Standards and the Malcolm Baldrige Award criteria, to gauge the progress of the quality system. The SSBU's Total Quality Management system is customer-focused—in all business areas, for all products and

Figure 3. The SSBU sets improvement goals for each of its deployment projects and their respective sub-projects—consistent with the directions and objectives of the Network Systems Group.

Policy deployment

Network Systems Group directions	Deployment projects	Switching sub-projects (priority activity)
Exceeding customer expectations	Customer evaluations	Customer evaluation report cards
		Customer report card coverage
	Satisfaction	Customer value added (CVA) index
		Reliability
	Order realization	On-time delivery
		Meet customer request data for all products
Enhancing quality	New product introduction	Improve rate of new product introduction
	Baldrige Award	Improve quality
Engaging people	Employee involvement	Results of AT&T employee opinion survey
		People value added (PVA) index
Increasing shareowner value	Market leadership	U.S. market share growth
		Global market share growth
		Communication Services Group market share growth
	Financial commitment	Financial commitment

services—to respond to the dynamic and competitive nature of the business.

Operational Elements

The operational elements that direct the SSBU's continuous improvement are *strategic quality planning*, *quality in daily work*, and *continual assessment* of the overall approach, as described below.

Strategic Quality Planning/Policy Deployment. In the SSBU, the strategic quality planning element of TQM is implemented through *policy deployment*, both a top down and bottom up process used to translate a vision or direction into coordinated action plans throughout an organization. Consistent with AT&T's Network Systems Group's strategic intent and the SSBU's business vision, the SSBU sets improvement goals for each of eight deployment projects and their respective sub-projects—all guided by the directions and objectives of the Network Systems Group (See Figure 3). These projects and their goals are then cascaded, that is, socialized and distributed, through each level of the organization.

Action plans are developed until the goals are appropriately represented in individual assignments, thereby linking each employee of the SSBU to the organization's high-level goals. A typical cascade of one of the goals is shown in Figure 4.

Progress toward the achievement of SSBU-level policy deployment for sub-projects is updated monthly and posted prominently on bulletin boards at all SSBU locations. Progress toward goals within the various SSBU units is tracked and managed by their individual management teams. For example, progress is evaluated quarterly against three levels of confidence:

- *Green*: progress toward the goal is good, and achievement of the goal is highly likely.
- *Yellow*: progress toward the goal is adequate, and there are some potential problems in reaching the goal.
- *Red*: progress toward the goal is unsatisfactory, and achievement of the goal at current rates of progress is unlikely.

Recovery plans for projects with "red" or "yellow" status are then prepared, reviewed, and appropriate actions taken, including the reallocation of necessary resources for "red" status projects.

Annually, in addition to reviewing the results

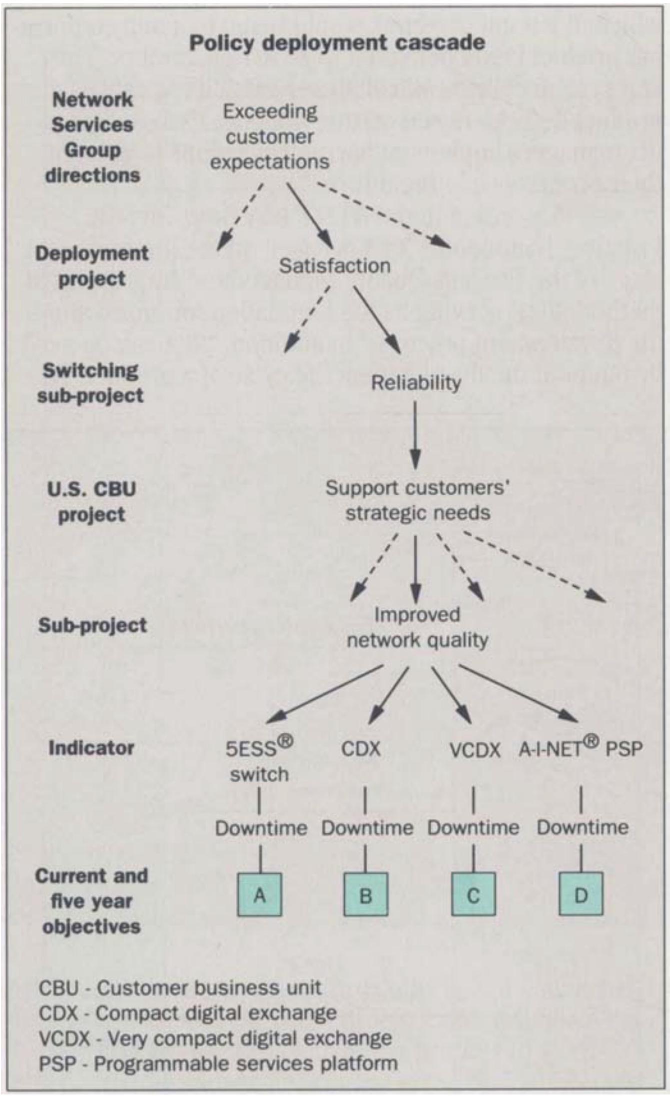

Figure 4. Action plans are developed for each of the SSBU goals, and they are appropriately represented in individual assignments at each level of the SSBU. A typical cascade of one of the goals is shown here.

achieved, the policy deployment process and schedule for setting goals is reviewed and improved.

Quality in Daily Work and Process Management. Process management now complements the SSBU's traditional strength in day-to-day project management, as well as continuous improvement in the quality of its products and services. Process management is grounded in AT&T's Process Quality Management Improvement (PQMI)[2] methodology. Process management teams follow a process description that guides them through the steps of PQMI. A PMT manages and improves the policy deployment process, for example, using the process management process.

SSBU processes are thoroughly documented and process architectures define the relationships and interrelationships of each unit's work processes. In some cases, *common processes* serve the needs of large cross-sections of the SSBU. In other cases, processes are *shared* between projects, with appropriate steps customized for unique needs. Finally, some projects may have processes that are defined to be applied *only* in their areas of responsibility. In order to advance all of the SSBU's processes to best-in-class as quickly as possible, however, there is a continuing emphasis on increasing the proportion of shared and common processes.

PMT membership consists of managers and non-managers. One manager is designated process owner and has accountability for the success of the PMT. Responsibilities of the owner include process planning, choosing the appropriate team members, allocating resources for the PMT, and driving the process to best-in-class. Another manager, designated the process "angel," is responsible for coordinating the various tasks performed by the team.

The PMT as a whole performs the work associated with process management and improvement, that is, designing and documenting the process, maintaining process documentation, collecting and analyzing process data, and proposing and sponsoring process improvements. Process improvements, in turn, are designed and implemented by quality improvement teams. A formal problem-solving methodology, the quality improvement story,[3] is used to guide the work of the QITs.

Several tools and techniques have been developed to support the work of the PMTs in making and sustaining improvements and eliminating defects from the SSBU's products and services. These include *product quality assessment*, *root cause analysis*, and *customer value added*. These tools are described in the section below, "Quality Improvement and the Customer."

Current emphasis on process management within the SSBU is simplifying its development processes, implementing best-in-class practices, and "clustering" processes to facilitate cross-process and cross-functional improvements.

Assessment: ISO 9000, CQA, Baldrige Award. The SSBU's TQM approach is rigorously assessed using external verification. One assessment measure is ISO 9000. All members of the business unit are committed to attaining and maintaining ISO registration, and major portions of the development community have achieved ISO 9001 registration in accordance with TickIT, a specialized ISO certification process for software development.

Independent ISO registration and maintenance audits validate the effectiveness of internal auditing programs, and also provide valuable feedback on the weak links in the SSBU's quality management system.

The SSBU also has participated since 1991 in the annual AT&T Chairman's Quality Award process. This assessment, which has led to steady improvements each year, is based on the Malcolm Baldrige National Quality Award criteria. The assessment identifies "gaps" in the SSBU's overall approach to quality management. These gaps are then targeted as projects for policy deployment and other improvement efforts.

The infrastructure for the SSBU's Total Quality Management System is well-established and the focus is now shifting toward accelerating the rate of improvement—consistent, of course, with achieving the unit's business vision.

Quality Improvement and the Customer

As already noted, switch reliability is clearly the top priority of SSBU customers, and its response to that priority has resulted in the development of the most highly reliable switch in the marketplace. A key element of that response has been the development of the two automated quality information systems, *root cause analysis* and *product quality assessment*, described below. Each information system plays a key role in the task of finding and removing product defects that degrade reliability. Since this task is heavily dependent on the timely availability of significant, accurate data, the automation of these information systems was regarded as crucial to meeting this need.

Fault Prevention with RCA. The root cause analysis system provides for a systematic analysis of defects to prevent them from re-occurring in existing or future deliveries of a product. Product defects are errors incurred during the product development life-cycle which, if left uncorrected, would result in a non-conforming product being delivered to AT&T customers. The RCA system collects and analyzes data on the causes of product defects. Based on this analysis, PMTs and product managers implement corrective actions to prevent their occurrence in the future.

According to the AT&T RCA Best Current Practices handbook,[4] "RCA is based on the improvement stage of the Process Quality Management Improvement methodology, serving as the foundation for improving the development process." In addition, "RCA can be used throughout the development life cycle of a product. To

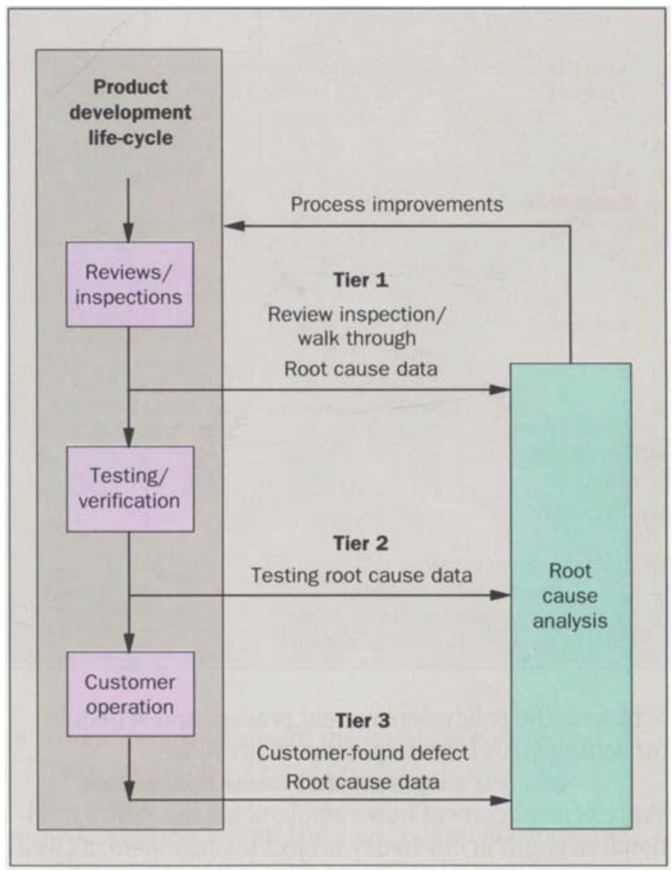

Figure 5. Data for root cause analysis (RCA) is collected at three levels, or tiers, of the product development life-cycle: reviews and inspections; testing and verification; and customer operation. Each set of data on errors is evaluated by use of RCA to improve processes.

Defects found	RE	AR	DE	DA	CO	UT	SP	FT	SyV	SV	FF	
Defects injected												Total injected
RE	7		3		18	102	4	84	5	9	50	282
AR			1		2	11	1	3			2	20
DE			19		42	502	26	230	31	6	40	896
DA				3	6	64	23	19	2	1	5	123
CR					11	25	24	22	1		4	87
CO					275	1779	144	517	69	24	145	2953
SP							26	1			1	28
Total found	7	0	23	3	354	2483	248	876	108	40	247	4389

AR - Architecture
CO - Coding
CR - Code reuse
DA - Data development
DE - Design
FF - Field found
FT - Feature test
RE - Requirements
SP - Software production
SV - Site verification
SyV - System verification
UT - Unit test

Figure 6. An analysis of 4389 defects demonstrated where they were introduced and where they were detected. The analysis helps detect processes that may be inherently introducing or detecting a particular type of error.

perform RCA, data on errors are collected and analyzed throughout the development process, and the results of the analysis are used to change the process to eliminate or reduce the incidence of similar errors in subsequent development projects."

Overview of the RCA Data Collection System. To assist PMTs in the prevention of defects, RCA data are collected at multiple points within the SSBU development process. At each of these points, the derived root causes of defects are used by the PMTs to identify process changes that will reduce the incidence of defects.

An overview of the RCA data collection framework is shown in Figure 5. Project-wide RCA data collection is categorized into three distinct tiers, which divide the data into meaningful classes for purposes of identification and reporting.

Tier 1 data are pre-testing defects identified in document reviews, code inspections, and code walk-throughs. Document and code authors, with the assistance of moderators, supply RCA information on a sample of defects found during the reviews, inspections, and walk-throughs.

Tier 2 data are defects found during testing or the use of the product during development. They are reported via internal trouble reports. Tier 2 RCA data collection is invoked automatically by the internal trouble ticket tracking system as product defects are closed. The trouble ticket already has data as to where the defect was *found*, since this data was entered when the ticket was opened. Therefore, a series of questions are asked of the person closing the trouble ticket to ascertain where the defect was *introduced*. The data are then collected in a centralized database and made available to all development teams worldwide.

Tier 3 data are defects found by all customers after the product is delivered. Tier 3 data collection and automation are identical to Tier 2 techniques, and use the same database.

Data Analysis and Areas for Improvement. The goal of data analysis is to identify areas for process improvement. The methodology of the quality improvement story is used to identify countermeasures for the problems cited by the analysis. Standard techniques used to determine categories of errors include *Pareto analysis,* to identify high runner defects, the *affinity diagram,* for identifying key process problems using a method of systematic brainstorming, and *chi-square analysis,* for identifying the significant differences between similar sets of data.

Figure 6 demonstrates that, by analyzing both where the errors are introduced and where they are detected, the analysis and subsequent improvements are easier to make. This is due to the fact that certain classes of defects are found and introduced by processes that may inherently introduce or detect a particular type of error. Once the team has identified key problems contributing to the creation of defects in the process, it prioritizes and documents the problem areas, based on their relative importance.

Implementing Process Improvements. Once the PMTs have analyzed their root cause analysis data and identified areas for improvement or themes to pursue, they set objectives via quality improvement projects (QIPs), which become part of their overall plan for improvement. Since one of the process team's key process metrics is *injected product defects,* process teams are expected to identify specific QIPs that are intended to address defect prevention.

Software Product Quality Assessment (PQA). The mission of software product quality assessment tools and structures is to track the progress of meeting the established goals for delivered software quality products. If it is determined that the quality goals will not be met or exceeded, action can be taken to improve the quality of the product prior to release.

PQA provides for the measurement of software quality at all development phases, and affords the opportunity to improve the quality of the product prior to its being released to the customer. PQA provides quality control, quality measurements of processes already executed, the prediction of software quality in processes not yet executed, and quality improvements due to real-time assessments of new processes and their effects on the quality of the product.

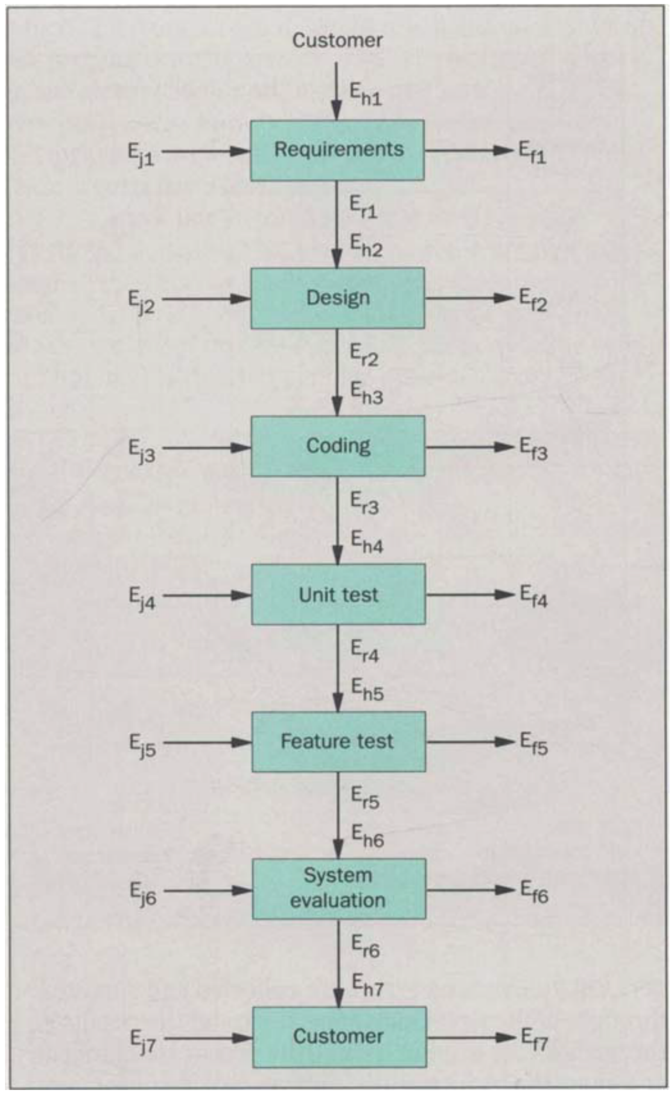

Figure 7. There are four variables for errors: E_h — errors inherited from the previous development phase; E_i — errors injected during the development phase; E_f — errors found during the current development phase; and E_r — errors remaining after the current development phase.

The PQA software quality is measured by error density, which is defined as the number of predicted errors after the completion of each development phase, divided by the number of source lines of developed software. The number of errors remaining after each development phase is defined as the number of errors originally *present* in the phase, minus the number of errors *found* during the development of the phase. The number of errors in a phase can be split into the number of errors *inherited* from the previous phase and the number of errors *introduced* during the development of the phase. This results in a model with four error variables for each development phase, as illustrated in Figure 7. These four variables are:

E_i — Errors introduced during the development phase. This number of errors is determined after all phases have been completed. The RCA data for every solved error provides an answer to the question of which phase injected the error. If all phases have not yet been completed, the number of injected errors in a completed phase can be estimated from historical data.

E_h — Errors inherited from the previous development phase. This number of errors is equal to the number of remaining errors in the previous phase.

E_f — Errors found during the current development phase. This number is determined automatically, since the process where the error is found is noted in the trouble ticket.

E_r — Errors remaining after the current development phase. The number of inherited errors, injected errors, and found errors are all determined or estimated. The number of remaining errors is simply the sum of the number of inherited errors and the number of injected errors, minus the number of found errors.

These four error variables can be determined after the software development has been completed. During the development, several error variables can only be estimated, based on historical data.

In addition to the variables for software errors, mentioned above, the *removal efficiency metric* is used as well. This removal efficiency is the number of found errors divided by the sum of the found errors and the remaining errors:

$$\frac{\text{Errors found}}{\text{Errors found + errors remaining}}$$

With an estimated removal efficiency of a phase, the injected errors and remaining errors can be computed. Removal efficiency can be estimated from historical data.

Customer Value Analysis. In the early years of implementing TQM in switching, a significant emphasis was placed on SSBU *conformance measurements*. The belief was that by meeting these internal conformance standards, the SSBU products and services would be accepted in the market. The SSBU customer focus, obviously, was reactive, based on responding to customer complaints.

By the end of 1992, however, the SSBU concept of customer focus had evolved to a more proactive program, in which feedback was actively sought through the extensive use of *customer report cards*. The focus of the report cards was on improving customer satisfaction, which is defined as the degree to which the unit meets or exceeds a customer's expectations.

The next step in customer focus, now called customer value added, recognizes that customer satisfaction should be viewed in *relative* terms. The CVA approach provides for a set of processes and tools for assessing customers' relative perceptions of AT&T's products and services—in comparison to those of the competition. The key result of this measurement is the ability to not just gauge a customer's satisfaction, but to develop strategies to improve it in ways that create sustainable competitive advantages.

The development of the CVA concepts within AT&T was led by R. E. Kordupleski and W. C. Vogel, Jr., who performed a study of customers' price and quality perceptions in the post-divestiture long distance telephone market.[5] That study included a series of surveys between 1986 and 1990. The resulting analysis of the data offered valuable insights, and strongly influenced AT&T's strategy in that market.

More surprisingly, it was found that customers' perceptions provided an accurate predictor of market share, which followed the fluctuations in perception by about four months with a correlation coefficient approaching 1. The work of R. D. Buzzell and B. T. Gale[6] also was significant in establishing the relationship between customer's perceived value and the resultant market performance.

The use of CVA as a tool for measurement and analysis grew out of Kordupleski's work, and is being widely implemented throughout AT&T.

The CVA Premise. Using CVA as a tool for managing customer satisfaction derives from three fundamental concepts:

- Customers buy based on value. Customers make their

purchasing decisions based on who offers the best value from among a complex set of choices involving differing prices, features, and availabilities.
- Value is based on a buyer's perceptions. It is a function of perceived quality, relative to perceived price.
- Value is relative. It is based on comparisons with other vendors that provide similar products and services.

CVA Data Collection. The shift in emphasis from measuring *satisfaction* to measuring *relative perceived value* in the marketplace implies significant changes in the amount and type of customer information gathered. Good data are crucial to the successful application of the CVA technique, and several sources have been utilized. Initial CVA calculations have been performed using data from the existing report card process, with competitor data obtained through market studies or consultants. The best source for data, however, has proved to be a comprehensive customer survey, including comparative data on SSBU performance versus its competitors'. Such a survey will ask customers to:
- Identify the key attributes that they consider important when selecting a supplier;
- Establish relative weights among those attributes based on their importance;
- Score the SSBU's performance, as well as its competitors', on each of those attributes; and
- Determine an overall score, for both the SSBU and its competitors, on the question of whether or not the products and services purchased were worth the price paid for them.

CVA Calculation. The CVA metric, as a single figure of merit, is primarily determined by customers' responses to the question "Is it worth what you paid for it?" This data, combined for all customers, is used to generate an overall index of perceived value for the SSBU and its competitors. The CVA calculation is then defined as:

$$\frac{\text{Perceived AT\&T value}}{\text{Perceived competitors' value}}$$

A CVA greater than 1.0 can be interpreted to mean that AT&T delivers greater overall value than the competition.

Quality Improvement. Strategies for improving the customers' perceived value of SSBU's products and services can be identified by analyzing the important attributes identified in the customer surveys. The first step is to separate these attributes into the categories of *price* and *quality*.

Price factors include:
- Initial price, including installation costs, and
- On-going costs, such as growth, maintenance, support costs, etc.

The quality category includes all non-price attributes, with particular attention to:
- Product quality, such as features, functions, and ease of use;
- Service quality, such as sales, delivery and installation, billing, and support; and
- Business relationship quality, such as strategic compatibility, integrity of commitments, and responsiveness.

Weighted scores for each attribute are combined to arrive at quantified indexes of perceived quality and price satisfaction. These two expressions are then plotted on a value map,[5] as shown in Figure 8. Value maps are used to relate the indexes of relative price satisfaction and relative perceived quality to shifts in market share between competitors.

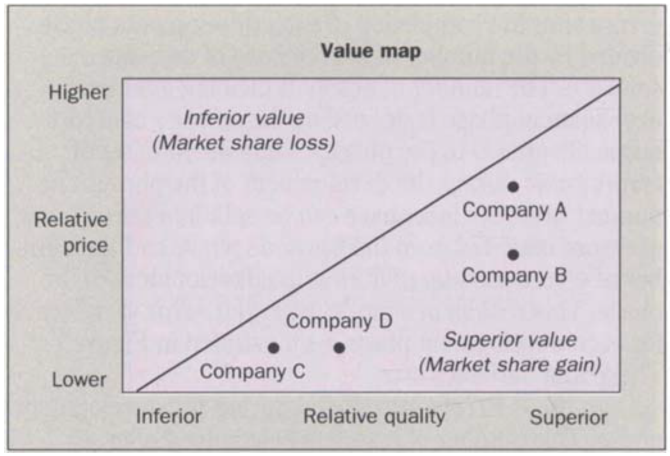

Figure 8. Value maps are used to relate the indexes of relative price satisfaction and relative perceived quality to shifts in market share between competitors. Weighted scores for each attribute related to price and quality are then combined to arrive at quantified indexes of perceived quality and price satisfaction.

As shown in Figure 8, a company perceived to be in position B can be expected to take market share from one in position A, because of the lower perceived price for an equally perceived quality. Similarly, a company at position D can be expected to take market share from one at position C, because of the greater perceived quality for an equally perceived price. Buzzell and Gale found these relationships to be valid in a number of industries, from automobiles to franchise food operations. Kordupleski and Vogel showed them to be valid in telecommunications equipment and services, as well. In addition, they demonstrated the use of such maps as accurate predictors of future market performance.

The identification of opportunities for improvement requires an examination of the individual attributes. The scores, relative to the SSBU's competitors', show the attributes most in need of improvement, and the weights assigned by customers make it clear which attributes are most important to them. Attributes that show a significant gap in score, and also are heavily weighted as important by customers, are obvious candidates for improvement. The processes that control performance on these attributes are identified, and their respective PMTs are responsible for making the necessary improvements.

CVA Vision. CVA is a tool that combines both measurement and predictive capabilities with the ability to identify and focus on improvement opportunities. It allows the SSBU to understand its customers' prevailing values, beliefs, and attitudes, and how they influence a customer's buying decisions. By responding to customers' needs with appropriate action, the unit is able to differentiate itself from its competitors, and position itself as the vendor of choice.

Conclusions

The high reliability of the 5ESS switching system is the result of a conscious and concerted effort to continuously improve its product quality in the areas most important to its customers. The Total Quality Management system used in this effort is driven by two axioms of the AT&T Quality Policy:

- Unqualified customer satisfaction, and
- Continuous quality improvement.

The two automated quality information tools, RCA and PQA, are examples of quality improvement efforts in response to customers' demands for reliability. The description of the CVA technique exemplifies the SSBU's continuing effort to improve the customer satisfaction process itself. Together, they are evidence of AT&T's determination and ability to continuously raise the standard of excellence on which its customers depend.

(Manuscript approved August 1994)

References

1. FCC Outage Report 43-05, ARMIS Quarterly Service Quality Reports.
2. "Process Quality Management and Improvement Guidelines," AT&T Customer Information Center, Indianapolis, IN.
3. "QI Story: Tools and Techniques," Qualtec Quality Services, Inc., North Palm Beach, FL., 1991.
4. "Best Current Practices: Root Cause Analysis," AT&T Customer Information Center, Indianapolis, IN.
5. Kordupleski, R. E. and Vogel, W. C., Jr., "The Right Choice — What Does It Mean?," AT&T White Paper, Oct. 24, 1988.
6. Buzzell, R. D. and Gale, B. T., "The PIMS Principles," The Free Press, New York, 1987.

Ronald G. Basinger *is a director in the Switching Systems Business Unit in Naperville, Illinois, where he is responsible for margin management for switching systems. He previously managed the European Switching Development for Network Systems International, and had served as the quality manager for the international switching organization. Mr. Basinger received a B.S.M.E degree from Ohio Northern University in Ada, Ohio, and an M.S.M.E. from Purdue University in Lafayette, Indiana. He joined AT&T in 1966.*

Michael J. DiMario *is technical manager of the International Switching Customer Business Unit's Performance, Reliability and Quality Assurance Group at AT&T Bell Laboratories in Naperville, Illinois. He is responsible for international switching quality assurance and assessment, ISO 9000, the Malcolm Baldrige Award, quality technology research, quality project management, metric design, quality model development, and data analysis activities. Mr. DiMario has received B.S. and M.S. degrees in software engineering from the University of Wisconsin in Madison, and an M.B.A. degree in the management of research and development from the Illinois Institute of Technology in Chicago. He joined AT&T Bell Laboratories in 1982.*

Thomas C. Pingel is technical manager for Switching's United States Customer Business Unit's (CBU) Quality Systems Engineering Group in Lisle, Illinois. He is responsible for planning and directing the evolution of the CBU's Total Quality Management system, including special emphasis on strategic planning and supplier quality management. He holds a B.S. degree in mathematics from Purdue University in Lafayette, Indiana, and a M.S. degree in operations research from Lehigh University in Bethlehem, Pennsylvania. He joined AT&T in 1969.

Michael J. Urban is a technical manager in Switching's Quality Systems and Customer Satisfaction Department in Naperville, Illinois. He is responsible for business unit quality and process management, new product introduction processes and metrics, and the Network Systems Gate Process. Mr. Urban has received a B.A. degree in political science from Vanderbilt University in Nashville, Tennessee, a B.S.E.E degree from the University of Texas at Austin, and an M.S.E.E. degree from Stanford University in Palo Alto, California. He joined AT&T in 1979.