Towards a TQM-based Process Improvement System in Manufacturing

Leong, Chun-Shan, Arthur P. Preston

Motorola Broadband Communications Sector/General Instrument of Taiwan, Ltd. Department of Quality Assurance/Reliability, Taipei, Taiwan. (cliang@gi.com)

International Graduate School of Management, University of South Australia, Adelaide, 5000, Australia (arthurpreston@optushome.com.au)

Abstract

This paper describes the philosophical and practical management approach to improvement adopted by a major, American owned, Taiwanese electronics manufacturer. The approach is underpinned by three questions: (1) What are we trying to accomplish? (2) What change can we make that will result in improvement? (3) How will we know that a change is an improvement? Customers serve as drivers for improvement and various feedback loops within the production system cycle are used. The approach incorporates ideas from the literature on decision-making, change management, Total Quality Management, systems thinking and the Deming PDSA cycle into a practical framework for the TQM-based process improvement system. Although firm-specific, the approach draws heavily on collective firm experience in Motorola including reengineering, benchmarking, stretch goals and six sigma approaches. For instance, the challenge of breakthrough performance is reflected in the observation that when a goal of 10% improvement is set, managers or engineers can usually meet it with some minor improvements. However, when the goal is 1000% improvement, employees must be creative. The seemingly impossible is often achieved, yielding dramatic improvements and boosting morale. Even if an improvement process is incremental, it is necessary to evaluate it at regular intervals. It is suggested that the progress of an improvement process can be measured and demonstrated in terms of (1) The degree to which quality improvement projects are aligned with the company's business strategies, policies and guidelines; (2) Improvements in key operational and business performance indicators such as reduction in scrap rate, field failure rate, material defect rate, out of box audits defect rate, increase of inventory turn and saving from individual improvement projects, and (3) Changes in behaviors and attitudes such as the reduction of industrial relations conflicts, or the ease that procedures crossing a variety of functions are changed.

1. Introduction

While many manufacturing organization have achieved a good reputation for product and service quality, there is a continuing need for research in process improvement if organizations are to continue to meet customer expectations. This case study develops the philosophical and practical management approaches to improvement adopted by a major, American owned, Taiwanese electronics manufacturer. Fundamental to the approach are three questions:

What are we trying to accomplish?

What changes can we make that will result in improvement?

How will we know that a change is an improvement?

Also relevant to the process of change at Motorola has been the notion of working within a system. Brocklesby [1] highlighted that the specific characteristic of systems thinking is its preference to deal with wholes rather than reducing problems to their individual parts and treating these separately. A systemic view of the organization is dynamic with inter-dependent people, departments, equipment, facilities, processes and products, all simultaneously working toward a common purpose. A manufacturing system is an integrated set of business functions, encompassing all activities from raw material acquisition to final customer delivery. The process model (Figure 1) depicts a generic manufacturing system with its various information feedback loops. Feedback comes from suppliers, directly from processes and from customers and provides a basis for action and improvement.

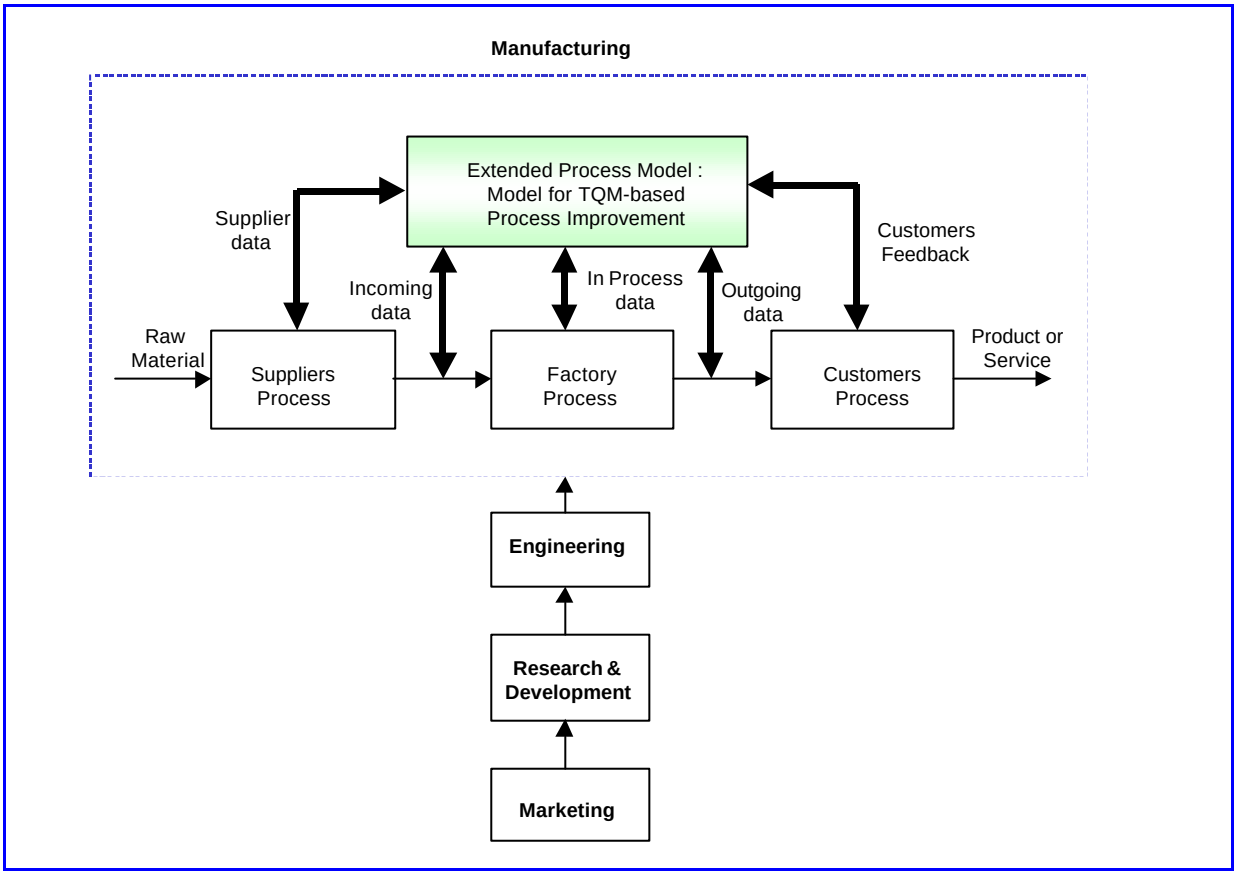

Figure. 1 The manufacturing system

As well as recognition of the requirement if a systems perspective, the Motorola approach blends sound decision practice, traditional improvement via TQM and the PDSA cycle, benchmarking and reengineering. The following sections briefly outline these approaches.

Decision making in the improvement process

Decision theory uses of models of judgments involved in and leading to deliberate, usually rational, choice. The decision making process basically involves three steps: The collection of information, the analysis of alternatives and the choice among the alternatives.

TQM-based PDSA cycle and process improvement

Motorola's approach to improvement has long involved TQM. TQM is a philosophy or approach to management that is grounded on three core principles {Evans and Lindsay [2]}:

- A focus on the customer

- Participation and teamwork
- Continuous improvement

The general steps in any process improvement project include defining the process and its boundaries, gathering data about the process, developing and testing hypotheses, and testing and implementing successful improvements. An easy way to conceptualize the steps of process improvement is to visualize the "Plan-Do-Study-Act" (PDSA) cycle. The PDSA cycle is a methodology for improvement. The cycle is never ending; that is, it is focused on continuous improvement. The Deming cycle is based on the premise that improvement comes from the application of knowledge. Through a process of learning, knowledge for improvement is developed. Combining TQM elements and PDSA cycle result in the TQM-based PDSA cycle. This guides the continuous improvement process where team-generated decisions lead to constant, incremental change to improve organizational performance and customer satisfaction.

Reengineering and process improvement

Motorola also uses reengineering. Reengineering is an approach to improvement that Hammer [3] claimed could be differentiated by its emphasis on radical redesign of business processes, but otherwise shares much in common with more traditional quality improvement approaches which are also based around processes change. Successful reengineering requires fundamental understanding of processes, creative thinking to break away from old traditions and assumptions, and effective use of information technology. The approach at Motorola assumes that it is appropriate to start with a clean slate and to proceed guided by three fundamental questions.

- What is the fundamental purpose of the process?
- How does the process create value for customers?
- What do customers really want but think is impossible?

Other guidelines used include the consideration of:

- Customer requirements and outputs of the process in light of current technologies and employee attitudes.
- The nature of cross-functional processes which go beyond its existing boundaries to redefine how something might be done differently.

Finally, and throughout, it is necessary to constantly ask: 'Why', and 'What if'.

Process improvement through benchmarking

At Motorola it is realised that the attainment of and improvement objectives, particularly stretch objectives, is often aided through a benchmarking process. Benchmarking is a reengineering/continuous improvement technique and its primary objective is process quality improvement.

2. The improvement model

The basic framework of the TQM-based Process Improvement System (TQM-PIS) used at Motorola is shown in Figure 2. The TQM-PIS begins with goal setting for improvement, followed by a decision-making process phase (the collection and analysis data and identifying improvements). Then comes the never-ending continuous improvement Deming PDSA cycle. Some of the benefits achieved in three years though the TQM-PIS implementation include:

- Inventory turns increased from 10 to 25,
- Scrap rate reduced from 0.5% to 0.2% of sales,
- Productivity improved from 95% to 98%,

- Annualized Field Failure Rate (AFFR) reduced from 0.4% to 0.15%,
- Out of box audits defect rate improved from 3000 to below 500 PPM,
- Prime pass yield improved from 90% to 95%, and material defect rates decreased from 1500 to 900 PPM.

The details and procedural steps associated with each phase are as follows:

2.1. Phase I: Goal setting

The purpose of phase I is to set the goal for the process improvement and all required activities. Motorola process improvement is always done in the context of goals and objectives. Goals and objectives are needed in each area where performance influences effectiveness. As soon as goals and objectives are adequately established, employees will focus on what results must be achieved and the measures that indicate whether they have been achieved.

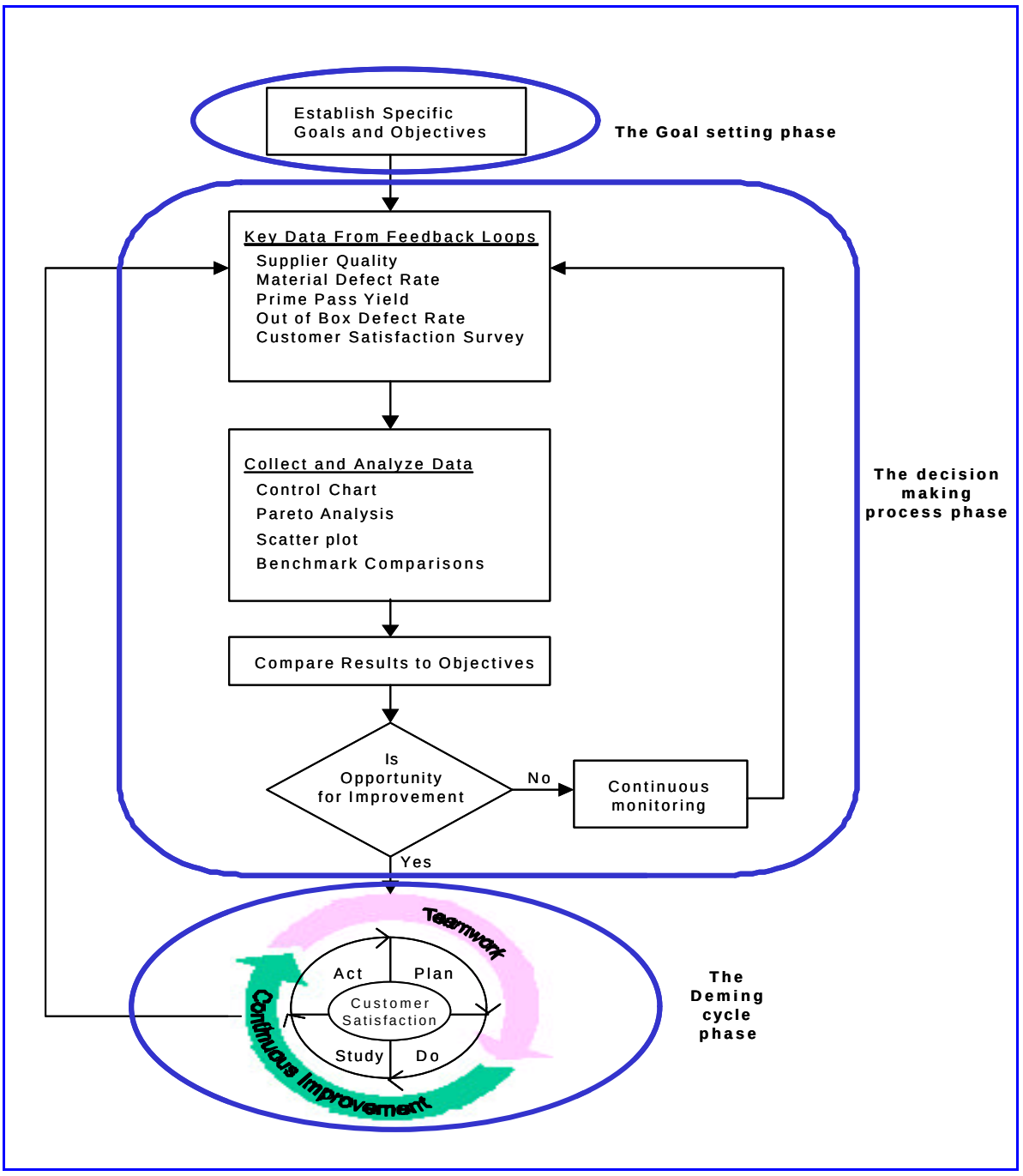

Fig. 2 TQM-based Process Improvement Model

Every manager and employee throughout the Motorola is using the Performance Excellence Scorecard goals as a base and adapts this goal to his or her own goals. Motorola Performance Excellence Scorecard system was developed to align between quality strategic objectives and company's business strategies. Measures like prime pass yield, material defect rate are tracked daily, weekly and monthly for improvement. Motorola also uses an employee performance measurement system called Personal Commitment (PC). This links business objectives and behavior to achieve business objectives. Employee performance assessment includes business results and behavioral evaluation. The "result" portion is to assess how the employee has performed towards PC goals. The assessment items of "result" are quality of work, adaptability to changing conditions, value adding of results, and the addressing the right issues with the right people at the right time. The "behaviors" portion is an assessment of competencies

against the "4e's plus Always 1e" defined by Motorola corporate. This approach is outlined below.

Motorola 4e's + Always 1e :

- eNVISION - Identifies meaningful and innovative change that produces profitable growth. Comes up with the vision, strategies and viable plan that achieve it. For example, strategic planning ; maintains industry awareness; innovation .
- eNERGIZE - Excites employees, customers, and partners around winning ideas. Brings extraordinarily high personal energy to everything. Creates an environment where everyone has a passion to excel and an opportunity to contribute. For example, builds & sustains relationships; coaches for performance; communicates with impact; develops and leads the team; demonstrates personal energy.
- eDGE - Cuts to the essence of what is important. Makes bold, timely decisions. Insists that the organization outperform expectations. Brings a healthy dissatisfaction with the way things are. Makes tough calls when the business or individuals are not performing. For example, demonstrates boldness; demonstrates decisiveness; demonstrates incisive thinking.
- eXCUTE - Achieves results significantly better and faster than our competitors by employing innovative, proven and rigorous management practices. Personally meets commitments and keep promises. For exa mple, plans and organizes; builds bench-strength; demonstrates personal productivity; focuses on client service.
- The always '1e' is:
- eTHICS & CHARACTER - Conducts business ethically always and everywhere. Treats all people and all cultures with respect and dignity. Keeps one's personal ambitions and emotional reactions from interfering. For example, demonstrates respect for others; displays professional integrity.

Goal setting will generally result in improved performance provided some general guidelines for goal selection are followed. At Motorola the setting of stretch goals is practiced regularly because the payoffs have been found to be great. Stretch goals require thinking about problems and situations to be radically different. When goal of 10% improvement is set, managers or engineers can usually meet it with some minor improvements. However, when the goal is 1000% improvement, employees mu st be creative. The seemingly impossible is often achieved, yielding dramatic improvements and boosting morale. Goals should be set in SMART (Specific, Measurable, Attainable, Relevant and Time-Bound) terms.

Motorola uses defects per unit as quality measure throughout the company. A unit is any output of work, such as a solder connection or a page of document. A defect is any failure to meet customer requirements. Six Sigma, which was developed at Motorola, allows, at most, 3.4 defects per million units. One of Motorola's current goals is a 10-fold improvement in cycle time every five years. For example, in 1996 Motorola achieved a defect rate of 2000 per million opportunities in the board level insertion wave solder process for a Cable TV converter. This defect rate was equivalent to a sigma quality level of 4.4 sigma. The stretch goal set by Motorola engineering and production team was five sigma quality level [233 defects per million opportunities (DPMop)] by 2001. The Motorola team was aware that the only way to achieve five sigma quality levels and to progress further (towards the six sigma) was to redesign products and processes. The team changed the board design from single layer PCB (Printing Circuit Board) to 2 layer PCB and changed the process from insertion to gluing wave solder in 1997. The defect rate was improved to 1000 DPMop. In 1998, the team then changed the board design to 4 layer PCB and process from gluing wave solder to re-flow continuously. The defect rate improved to 500 DPMop. In 1999,the board was redesigned to 6 layer PCB and the re-flow process retained. Overall defect rates have improved to 200 DPMop. The Motorola team has

thus achieved 10-fold improvement in three years for the PCB process.

2.2. Phase II : The decision making process

The purpose of phase II is to evaluate current performance, identify gaps between current performance and goals which were set in phase I, and then to reduce the gaps. Almost always, teams find it essential to understand in detail the current situation before they begin developing changes for improvement.

Phase II starts with the collection of information from the feedback loops. This is followed by the analysis of data using appropriate tools. Next performance is compared with goals. If the actual performance meets the objectives, then routine monitoring is established, and further diagnosis and improvement initiated. If not, then the Deming PDSA cycle (Phase III) is enacted. Note that this process relies heavily on the analysis of a variety of measurements and information. There are numerous quality tools for improvement that can be used in this phase. Some examples of these tools are given in Table 1. Each of the tools needs to be used judiciously.

Table 1 Overview of Methods and Tools for Improvement [4]

Category	Method or Tool	Typical Use of Method or Tool
Viewing Systems and Processes	1. Flow Diagram	Develop a picture of a process. Communication and standardize processes.
	2. Linkage of Processes	Develop a picture of a system composed of processes linked together.
Gathering Information	3. Form for Collecting Data	Plan and organized a data collection effort.
	4. Surveys	Obtain information from people.
	5. Benchmarking	Obtain information on performance and approaches from other organizations.
Organizing Information	6. Cause and Effect Diagram	Collect and organize current knowledge about potential causes of problems or variation.
	7. Tree Diagram	Visualize the structure of a problem, plan, or any other opportunity of interest.
	8. Quality Function Deployment (QFD)	Communicate customer needs and requirements through the design and production processes.
Understanding Variation	9. Run Chart	Study variation in data over time; understand the impact of changes on measures.
	10. Control Chart	Distinguish between special and common causes of variation.
	11. Pareto Chart	Focus on areas of improvement with greatest impact.
	12. Frequency Plot	Understand location, spread, shape, and patterns of data.
Understanding Relationships	13. Scatter plot	Analyze the associations or relationship between two variables; test for possible cause-and-effect.
	14. Planned Experimentation	Design studies to evaluate cause-and-effect relationship and test changes.

2.3. Phase III : The Deming PDSA cycle

After identifying that improvement is needed, the PDSA cycle is applied. Much of the focus of the Deming cycle is on implementation. Although the graphic of the PDSA Cycle represents the stages as being equal in proportion, we at Motorola have found that they are not. In reality the “Plan” phase is often the lengthiest part of the cycle. In this phase, the team must gather and analyze a great deal of data and other information about the process.

This step must be done thoroughly and accurately before going on to the next phase of the project because it establishes the framework within which decisions are made. If the data gathered are incomp lete, or inaccurately analyzed, the decisions will be based on faulty premises. The 'do' stage calls for the most creativity and imagination. It also requires the greatest tolerance-for new and radically different ideas, for supporting ideas other than one's own, and for ambiguity. At this point, implementation is still a distant goal although preliminary thoughts about testing possible solutions are formulated.

In the do stage, the plan is implemented on the trial basis, for example, in a laboratory, a pilot production process, or with a samll group of customers. This limited implementation is an experiment to evaluate a proposed solution and provide objective data.

The purpose of the "Study" stage is to evaluate potential solutions selected as being the most likely to succeed. These solutions can be walked through as a preliminary test, but also should be performed under actual conditions in order to get as realistic a picture as possible. The study stage determines whether the trial plan is working correctly and if any further problems or opportunities are found. Often, a proposed solution must be modified or scrapped. New solutions are proposed and evaluated by returning to the do stage.

In the last stage, 'act', the final plan is implemented and the imp rovements become standardized and practiced continuously. This process then leads back to the plan stage for futher diagnosis and improvement. The purpose of this stage is to carry out every detail of implementation. The end result should be a completely successful handoff of a new and improved process. This stage is most dependent on the good communication with and involvement by the home team.

As Figure 2 illustrates, the cycle is never ending; until current performance meets objectives. The improved process is springboard for further improvements.

The following example demomonstrates how the improvement model is applied at Motorola in practice.

Example : Cycle time reduction - eliminating burn-in process in a digital converter production line.

Normally the cycle time of 8 hours per thousand units is required for digital converter production line from board insertion, final assembly, testing, burn-in process and packing.The bottleneck in this process is the 4 hour burn-in process. The burn-in process was desighed for Analog product lines 15 years ago to screen out the early life failures using 40 Degree C high temparature.This process was copied onto the digital converter production line without questioning whether requirements were the same. There is opportunity to remove burn-in process in digital line.

The three fundamental questions were asked:

Q1: What are we trying to accomplish?

Improve the cycle time(from 8 to 4 hours/K units) of digital converter production line with eliminating burn-in process and maintaining same quality level.

Q2: How will we know that a change is an improvement?

- Less time to repair line reject units
- Fewer defect rate in finished goods inspection
- Improve productivity

Q3: What changes can we make that will lead to improvement?

Obtain information to better understand the burn-in process.Plan and carry out data-collection using the PDSA cycle.

■ Apply TQM-PIS Model

(1) Phase I: Stretch goal setting

Eliminate burn-in process for digital converter production line to improve 50% cycle time with maintain the same product quality level

(2) Phase II: The decision making process

Collect the data of production reject rate, failure mode and analyze the cause of defects during burn-in process. Based on the collected data,the reject rate due to burn-in process is low (0.2%). After identifying that improvement is needed, the PDSA cycle is applied.

(3) Phase III: PDSA cycle

PLAN:

Objective of cycle 1:Gain understanding into the burn-in process

Questions to be answered from the data obtained in this cycle:

- What are the top 3 failures after burn-in process?
- What percentage of the failures are caused by burn-in process?

Predictions: High percentage of the failures are nothing to do with burn-in process

Plan for change or test; collection data (WHO, WHAT, WHEN, WHERE):

Engineer A - Collect data with burn-in and without burn-in process at packing line test stations for two weeks.

Engineer B - Analyze data and run/make charts

DO: Carry out the change or test; collect data and begin analysis.

- Some trouble testing all of the data at packing line
- Computer records do not always match with hand written data

STUDY: Complete analysis of data; summarize what was learned

Based on collected data, the failure rate of packing line is 0.07% difference between with burn-in process and without burn-in process. There is no out-of-box defect rate difference for the products between original and new process. Burn-in room was used as a big heater to test digital parameters at high temperature (about 40 Degree.C ambient). Based on a lot of pilot run data collected in two weeks, the digital parameter degraded about 3 dB in average at high temperature compared with room ambient test condition.

ACT: Are we ready to make change? Plan for the next cycle.

Based on above data, the digital product burn-in process can be eliminated and move the digital parameter test station from packing line (after burn-in) to final line (before burn-in) with tightening the digital parameter screening spec. by 3dB at the final line. Implement standardized procedure for digital production.

The Objective of next cycle: Will develop and implement standardized procedure for non-digital production processes.

3. Discussion for Motorola practices

Process management reguires a disciplined effort involving all managers and workers in an organization. A number of fundamental prerequisites that are identified by the management of Motorola/BCS/GIT for the successful implementation of a process improvement system.

TQM environment

Total Quality Management (TQM) represents an improvement portion in Motorola process improvement system. Process improvement results from a disciplined and strutured application of the TQM principles. In order to assure success, the basic principles of TQM must permeate the entire organization. Customer focus, teamwork, and continuous improvement are TQM principles that foster synergy among employees from various functions.

(1) Customer focus

Key objectives for the company include gaining and sustaining management commitment to the challenge of meeting and exceeding customer focus while not incurring cost over-runs. Motorola management use the value-added approach into the customer-oriented focus of process management whereby daily priorities and activities through the operation are aligned with overall corporate goals to improve operational efficiency and current quality and customer service levels. At Motorola we believe that it is necessary to take into account all product and service features and characteristics that contribute value to the customers and lead to customer satisfaction, preference, referral, and loyalty. Value and satisfaction are be influenced by many factors throughout the customer's overall purchase, ownership, and service experiences. These factors include the organization's relationship with customers that helps build trust, confidence, and loyalty. To make the concept of "Customer first" as a part of Motorola culture, employees are encouraged to visit other factories to learn how they are managed for benchmarking. Managers are encouraged to visit customers to understand what they needs and how our products and services are actually provided. Customers serve as major drivers for improvement.

(2) Teamwork

The ability of an organization to turn the diversity among its employees into a complimentary strength is another indicator of the maturity levels of its process improvement system. Motorola is using TQM provide employees with the goals, information, and time needed for process improvement that affect quality. Process improvement teams are the key part of the continuous improvement process. These teams consist of anyone who may have knowledge about the problem. Many process improvement teams are cross-functional, drawing personnel from different (most likely interacting) departments. Process improvement teams are given a problem to solve. The team must be given clear directions for conducting and concluding the process. In Motorola, process improvement team usually consists of six to eight people. One person is drafted as the facilitator, and another as the meeting recorder. The leader is responsible for activities like setting the goals, the agenda, and arranging meeting times. The facilitator is charged

with ensuring the everyone has a chance to speak at the meetings, that no person is attacked for airing unpopular view, and so on. The recorder takes the minutes and reports after each meeting to the steering management teams about the process improvement team's progress.

Mutual respect among employees is the other general aspect of the organizational culture that is paramount in importance for the successful implementation of process management. One of the key issues within the process management approach as stated above is the ability to seek opportunities for improvement as separate from problem correction – innovation is an essential aspect of this process. It is not realistic to expect anyone to have all their new ideas work out well– innovation and failure are close neighbors. Fear of ridicule and punishment are two roadblocks for innovation that must be totally absent in the corporate culture of any organization that hopes to adopt TQM principles. Mistakes by any employee need to be treated as learning opportunities for every employee. One of the key beliefs of Motorola is "constant respect for people". This means we treat others with dignity, as we would like to be treated ourselves. Constant respect applies to every individual we interact with around the world.

(3) Continuous improvement

Process management includes actively seeking out opportunities for improvement by reviewing issues that may not appear problematic. The guiding spirit of Motorola process improvement system is the thirst for improvement that goes beyond the focus on doing things right and embraces looking for ways of doing things better. Motorola continuously improves quality and overall performance. As well as core production process, Motorola examines all business process and support services such as finance and accounting, purchasing, facilities management, design engineering, and Human Resource services. For example, employee morale, satisfaction, and cooperation improvements are initiated based on an annual employee climate survey. These improvement approaches rely heavily on the analytical approach to develop a variety of measurements and trends. Motorola believes improvement is a proactive task of management, not simply a reaction to problems. The mindset of quality is one of prevention and continuous improvement.

Issues

In general, it is often easy to attract the attention managers to improvement ideas. However, it is more difficult to obtain tangible and ongoing support. The current economic conditions make it necessary for all organizations to review and tightly control costs and expenditure; at such periods of time, management often has the tendency to put Quality on the back burner due to financial constraints. Ironically, it is at such times that the greatest opportunities for minimizing operational losses by the judicious prusuit of quality improvement projects exists. Motorola process improvement teams analyze each process improvement project to establish its relevance to the organizational goals and priorities, as well as the potential return on investment that is required for its implemention. It is clearly understood by Motorola management and employees that process management can and should withstand financial evaluation . Department head is required to justify all investments– including those related to process improvement projects! Normally the financial budget plan includes sections for investments and return on investments for the process improvement.

Poor quality costs the organization money. Good quality saves the organization money. Motorola has adopted a dollar-based reporting system called "Cost of Quality". This system pulled together all the costs related to developing the quality system and inspecting products, equipments cost used for reliability as well as the cost incurred when the product failed to meet requirements. This cost is documented in monthly reports to management.

4. Conclusion

The TQM-based process improvement system (TQM-PIS) provides a useful framework to carry out improvement. This framework includes three phases: goal setting phase, the decision-making process phase (systematically analyzing data and identifying improvements) and then the never-ending continuous improvement TQM-based PDSA cycle. The approach is guided by three fundamental questions (What are we trying to accomplish? What changes can we make that will result in improvement? How will we know that a change is an improvement?); and is applied across all organizational functions. It is consistent with the three tenets of TQM (customer focus, teamwork and continuous improvement). It applies and extends traditional practical ways to overcome the difficulies of implementing an improvement program. Using this approach, Motorola team members have worked successfully to reduce defects, shorten cycle time, and increase customer satisfaction.

References

[1] Brocklesby, J.; Using saft systems methodology to identify competence requirements in HRM, International Journal of Manpower, Vol.16, No.5, pp.70-84, 1995.

[2] Evans, R. J. and Lindsay, M.W.; The Management and control of Quality, 5th Edition, South Wesrwen Publishing Company, New York, 2001.

[3] Hammer,M. and Champy,J.; Reengineering the Corporate:A manifesto for Business Revalution,Harper Collins,New York, 1993.

[4] Associates in Process Improvement; The Improvement Handbook, Austin, Texas, 1997.