# DEVELOPMENT OF A MEASUREMENT-BASED APPROACH FOR MONITORING THE CHANGES IN AN EVOLVING QUALITY MANAGEMENT SYSTEM

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## ABSTRACT

The concept of quality management is operationalized in an organization through a Quality Management System (QMS) - a complex, coordinated set of activities and behaviors aimed at improving the quality of an organization's processes, goods, and services. Like all systems, a QMS must be planned, monitored, improved, and maintained over time to function at its best. For this, measurement is key.

The standard of quality management performance developed by Triantis, et. al. (1991b) is the quality management system definition used in this thesis. The thesis subsequently makes three contributions. First, it provides a methodology for defining generic measures of QMS performance and evolution, and implements this methodology in creating more than 200 prototype measures for 10 out of the 37 component "modules" of a QMS. Second, a methodology is presented for developing a tool to collect the very data called for by the measures. This methodology is implemented and a prototype questionaire developed to collect measurement data for the Vendor/Contractor Relations (VCR)

module of a QMS. Third, given the vast amount of data collected with the various questionnaires that needs to be manipulated in order to manage the QMS, it is important to be able to use automation. Therefore, it becomes necessary to logically organize the data. The entity-relationship (E/R) modeling technique is one approach that can be used to achieve this objective. This E/R approach is used to logically organize data that is generated by the questionnaire for the VCR module. In so doing, one can assess the potential viability of this data modeling appproach and begin laying the foundation for a database that will support the measurement requirements of a QMS.

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Vivek Caroli

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TABLE OF CONTENTS

LIST OF FIGURES

## LIST OF APPENDICES

# CHAPTER 1: OBJECTIVES, SCOPE, AND METHODOLOGY

## 1.1 INTRODUCTION

Competition is fierce in today's marketplace. Organizations must offer their goods and services to an increasingly complex world of consumers able to choose from an ever-expanding array of options. Advertising, pricing, brand name reputations, and multiple product/service features add to the many factors influencing consumer decision making, further complicating the work of organizations to stay competitive. In the face of such an environment, product and service quality become critical. Indeed, for companies to hope to maintain customers and achieve financial growth, their quality of goods and services must equal or exceed those of competitors and ever-improve with time.

Among the many methods, philosophies and technologies available to maintain organizational performance and improve it, is a concept called *Total Quality Management (TQM)*. Defined as "an approach for continuously improving the quality of goods and services delivered through the participation of all levels and functions of the organization," [Pfau (1989), p. 17] TQM may be applied to any business enterprise. Also known as *Strategic Quality*

*Management (SQM)* [Garvin (1988)], TQM is an expansion of earlier efforts to control quality through inspection and sampling. It affects all goods, services, and processes of an organization. In this thesis, the philosophy of Total Quality Management is referred to as TQM, SQM, or simply *Quality Management (QM)*.

The concept of quality management can be operationalized in an organization through a *Quality Management System (QMS)*. Such a system involves multiple behaviors and activities regarding materials, labor, processes, services, goods, vendors, consumers, and management, to name a few; all contribute to the ongoing maintenance and improvement of the quality of an organization's products and services. Just as the goods and services of an organization, however, must intentionally be monitored in order to be improved, the performance and improvement of a quality management system must itself be monitored to ensure its continued revitalization. Measurement facilitates this need.

Measurement can tell an organization if its quality management system is performing as it should. It can tell management how its system has done over time - what the system does well, not so well, and where adjustments are needed. In so doing, measurement can allow management to set priorities - to determine where energies and resources

are best applied. In short, the single most important reason for employing measurement is to provide information for improving a quality management system itself. Together, measurement and QMS revitalization hold the promise of creating strong competitors in today's global economy.

## 1.2 RESEARCH OBJECTIVES

The standard of quality management performance developed by Triantis, et. al. (1991b) is the quality management system definition used in this thesis. Subsequently, this thesis addresses three fundamental objectives:

1. To provide a methodology for defining generic measures for QMS performance and evolution and to define prototype measures for ten out of the thirty-seven modules of a quality management system.[1]
2. To define a methodology for developing a tool to collect the data called for by the prototype measures. This methodology is implemented by developing a questionnaire to collect data for the vendor/contractor relations (VCR) module of a QMS.

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[1] A "module" designates a fundamental component of a QMS. For more details, refer to the background information in Chapter 2, Section 2.1.

3. To use the E/R modeling technique as a possible approach for logically organizing the data generated by the questionnaire of the VCR module. The viability of the approach is assessed by tracing back to specific database requirements for this module and assessing whether these requirements have been met.

The first objective of this research is to identify and develop prototype "generic" measures appropriate for monitoring and reflecting changes in a QMS. To meet this objective, a methodology is presented and applied for creating performance measures for 10 modules of QMS. For maximum utility, the measures should be applicable to any work environment, i.e., "generic" in nature. The totality of measures must capture qualitative and quantitative elements of quality management. Measures need also reflect both operational and strategic parameters of organizational behavior given the powerful roles of each in managing for continued gains in quality.

To operationalize the above measures within an organization, a tool is needed for collecting the very data sought in the measures. Development of a data collection tool is, therefore, a second objective of this project. A methodology is presented to develop a questionnaire to meet this objective. For illustrative purposes, a questionnaire

is developed to collect the data for measures of the VCR module of the QMS. Measures for this particular module are among the set of prototype measures defined.

If effective, any collection tool will generate a given amount of measurement data. Analysis is needed to convert this data into useful information that may be used to improve/enhance the performance of the activities that are being measured. Should additional questionnaires be used to collect information about other modules of a QMS, even more measurement data will be generated. Thus the total amount of data available for analysis would be of a large magnitude.

With this scenario in mind, an automated system would be highly useful in storing, retrieving and manipulating measurement data that is generated by the questionnaires developed as part of the second objective of this thesis. A database is a system that comes to mind for meeting these needs. One of the first steps in designing this database is to logically the organize the data. The third focuses on the E/R modeling approach as a possible vehicle for logically organizing the data that is generated by the questionnaire for the vendor/contractor relations module. The potential viability of the approach for this specific case will be determined by tracing back to the data requirements and assessing whether these requirements have

been met. This exercise would have to be repeated for the remaining modules of a QMS to assess the usefulness of the E/R approach to logically organize all the data that is generated by all data collection tools. However, as a first step it is necessary to at least attempt this exercise for one of the many modules of the QMS.

## 1.3 METHODOLOGY

Figure 1 depicts an overview of the approach used in this thesis. To start, a methodology was developed for identifying and defining measures appropriate for a QMS. *Generic measures* - those applicable to any organization - were developed for the activities of 10 modules of a QMS as these activities/modules were originally defined by Triantis, et. al. (1991b). Measures were also developed for criteria and quality system activities not otherwise identified by Triantis, et. al. (1991b) but researched from the literature.

Next, a methodology was developed for preparing a survey tool - in this case, a questionnaire. The methodology calls for tailoring generic measures to the specific workplace and environment of an organization wishing to improve or monitor its QMS. According to the methodology, measures of quality judged to be most important

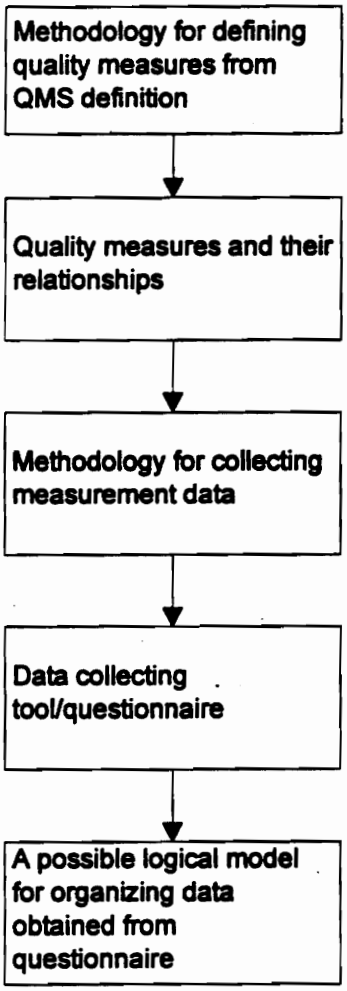


Figure 1. Methodology

and appropriate are to be selected from the pool of tailored measures and retained for final use in a questionnaire. Consistent with the philosophy of Total Quality Management, the methodology calls for the participation of the *customer* throughout this process. Upon completion of a final set of tailored measures, *instances* or examples for each measure are to be created; these instances are statements about the attributes of a product, service, or process being evaluated. A response format for the questionnaire is ultimately selected and an introduction written for the final questionnaire.

In this research, the above methodology was used to develop a prototype questionnaire for collecting measurement data specific for the activities of the *Vendor/Contractor Relations* module of a QMS. The questionnaire was developed for the unique needs of a sample organization called *Delta;* as called for by the TQM philosophy, *Delta* employees participated throughout the development process.

Once collected through a questionnaire, (quality) measurement data requires organization, storage, and analysis. In this research, a logical model was developed for the data generated by the prototype questionnaire of the Vendor/Contractor Relations module. The entity-relationship (E/R) modeling approach was specifically used to logically organize the data for the VCR module. This modeling work is

a first step in designing and creating a database for the QMS. The author envisions this effort as a starting point for a future quality information system.

## 1.4 SCOPE OF THESIS RESEARCH

When coupled with the earlier work of Triantis, et. al. (1991b), the methodologies, prototype measures, sample survey, and entity-relationship logical model presented in this thesis lay a practical foundation for operationalizing the TQM philosophy within an organization. This foundation may be applied to any organization - government or commercial, service- or manufacturing-based. Through use of this research, an organization can measure its revitalization in quality from both operational and strategic points of views.

This research may also be used to support organizational systems beyond those for quality measurement. Improvements documented over time (through QMS measurement) for a particular product, process, or service can serve as a basis for employee reward, bonus or recognition. When used external to an organization, the methodologies and measures developed herein can be applied to parties such as suppliers and vendors whose products or services have significant consequences for the organization. In the process of

contracting with new vendors, for example, an organization may utilize the measures to clarify the operating parameters for its vendors and to assess their quality management capabilities.

## 1.5 DOCUMENT ORGANIZATION

Chapter 1 sets forth the research objectives of this thesis. It includes an overview of the methodology used and the scope of the work. To facilitate the reader's fullest understanding, a list of the many QMS-, measurement-, and questionnaire-related terms appearing in this research are defined in Appendix A.

In Chapter 2, the reader is given background information on quality management systems. This Chapter establishes the importance of the research and outlines a set of assumptions that were made and relied upon in completing the work.

Chapter 3, presents a review of the literature. The review concentrates on: a) the history of quality management, b) the relationships between strategic quality management and business performance, c) features and components of excellence in quality management systems, and d) database modeling for organizing QMS measurement information.

In Chapter 4, a methodology is presented for developing generic measures appropriate for a quality management system. Included with the methodology is a set of prototype measures for ten of the thirty-seven modules of a QMS; these measures can be found in Appendix B.

Chapter 5 follows with a methodology for developing a tool to collect measurement data within an organization. A sample prototype questionnaire is presented (in Appendix C) for collecting performance-related data regarding Vendor/Contractor activities of a QMS, just one component (module) of a QMS.

Chapter 6 describes the application of the E/R model as an approach to logically organize the data created by the questionnaire defined for the VCR module in Chapter 5.

Final observations of this research are offered in Chapter 7, along with recommendations for future investigation.

# CHAPTER 2: BACKGROUND OF THE QUALITY MANAGEMENT SYSTEM, IMPORTANCE OF RESEARCH, AND ASSUMPTIONS

## 2.1 BACKGROUND ON THE QUALITY MANAGEMENT SYSTEM

Previous work by Triantis, et. al. (1991a, 1991b, 1992, 1993) has laid a foundation for understanding the structure and functioning of a quality management system. In 1991, this group identified numerous, comprehensive criteria for assessing the fundamental components of a QMS in any organization. Their quality criteria gave rise to a definition of a QMS involving thirty-seven sub-systems or *modules*. (See Figure 2) The modules reflect groups of behaviors and activities vital to an organization's quality management behavior, e.g., quality planning; employee involvement; and customer requirements, expectations, and satisfaction, among others [Triantis, et. al. (1991b)].

In defining a QMS, Triantis, et. al. (1991b) first defined modules as individual units. They considered each module as its own system and applied standard systems engineering principles to it. The research team identified the primary value-adding activities of each module and the primary inputs needed to perform these activities. They also identified the major value-added results or outputs of each module. The sum of all functions reflected in the thirty-seven modules constituted a "system" of quality

Leadership
Quality Measurement
Quality Planning (Strategic and Operational)
Quality Culture
Quality Policy
Quality Education and Training
Quality Management System
Deployment of Quality Tasks, Reporting and Communications
Quality Support Organization, Quality Responsibility and Authority
Interface Management (Organizational Relations) and General Management Systems Interface (Interface of the TQM System with other Management Systems/Activities)
Customer Relations/Commitment to Customers
Contractor Relations
Determining Customer Requirements, Expectations, Satisfaction
Human Resource Management
Employee Involvement
Behavioral Reinforcement/Recognition/Individual Performance Management
Employee Well Being and Morale
Documentation/Work Instructions/Quality Control Records
Management of Data and Information
Analysis of Quality Data and Information
TQM System Assessment/Quality Evaluation
Quality Costs
Quality Improvement/TQM System Enhancement
Research
Determining Competitive Comparisons and Benchmarks
Quality Assurance
Quality Management Results
Control
Marketing
Resource Allocation/Utilization
Design Assurance
Public Responsibility
Contract Performance (from the perspective of the contractor)
Production Process/Fabrication/Assembly
Material Handling/Storage/Delivery
Calibration
Completed Item Inspection & Testing

Figure 2. Component Modules of a QMS

management within an organization.

In formulating their definition, Triantis, et. al. considered two views for all modules as depicted in Figure 3. The first, a *bottom up* view, provides an operational perspective. This view allows one to address the functional details of the various management and production processes of an organization as they relate to the quality of processes, products and services. Modules identified by Triantis, et. al. and consistent with this perspective were grouped as *process level* modules. The second view applied by the research team was more strategic in nature. This *top down* view focused on management-based activities such as strategic planning, quality leadership, and quality culture, to name a few. Modules consistent with this perspective were called *enterprise level* modules.

Overall, the QMS work of Triantis, et. al. delineates the dynamic interplay between the many and complex elements of an organization's efforts to enhance the quality of its goods and services. The group's efforts offer powerful analytical, operational tools for understanding both single components of a QMS and the system as a whole. Used alone, however, the quality criteria and management system definition cannot be fully operationalized within an organization. Measurement is needed. This raises new questions: How might measures for a quality management

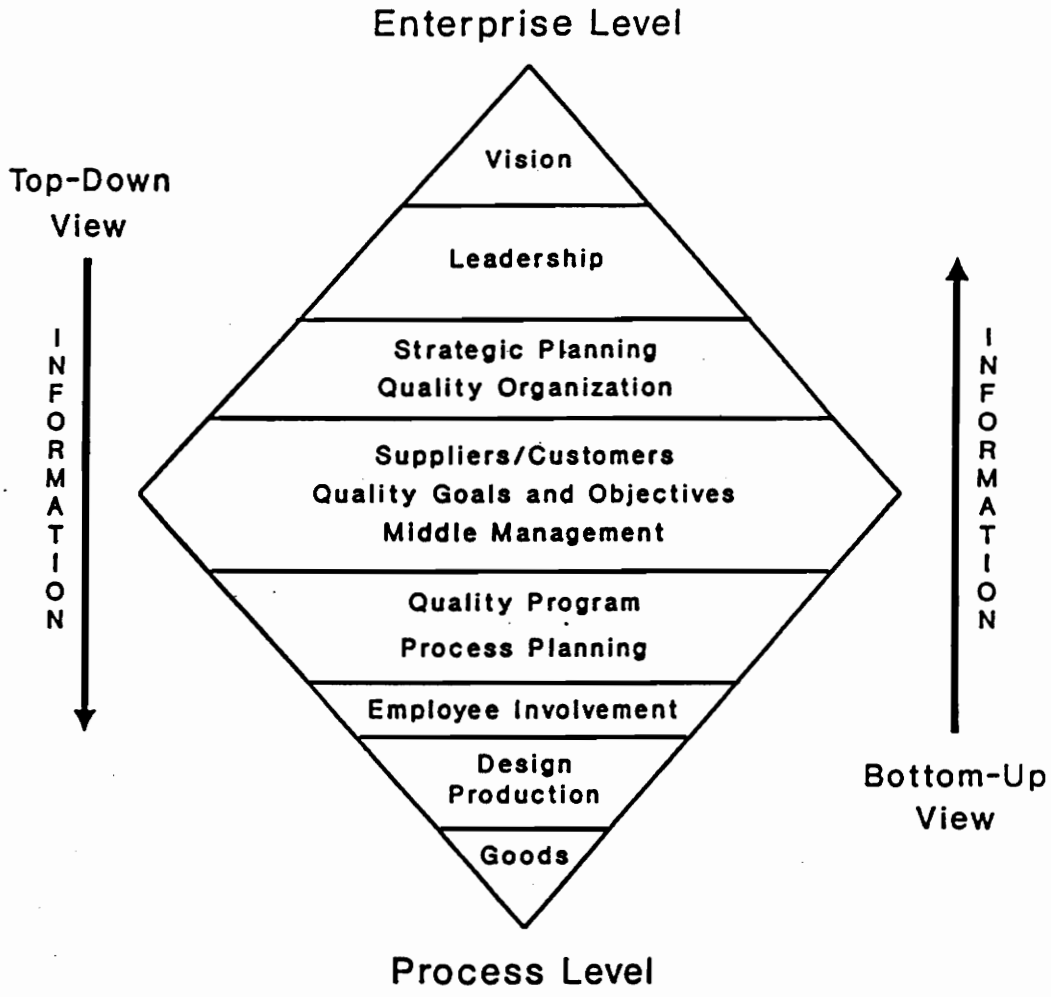


**Figure 3. Operational and Strategic View of a QMS**

system be derived? What measures of a quality management system's activities might best reflect the performance of the system as a whole?

## 2.2 IMPORTANCE OF RESEARCH

As previously stated, quality management systems hold the promise of creating fundamental change in the way organizations approach the need to continously improve their processes and service/product quality. Yet research is lacking on a key component of a QMS - the development and use of measures (or a measurement system) that can support a system's revitalization and continued improvement. The current research effort addresses this need.

Depicted in Figure 4 and described below is the cycle of developing or continuously improving a QMS. At each stage, measurement is needed. Consistent with the philosophy of Total Quality Management, the work presented herein allows for the full implementation of a QMS within an organization and the monitoring of its performance over time.

### 2.2.1 The Analysis and Assessment of An Organization's Quality Management Capabilities

Before initiating change in an organization, it is imperative to know where an organization is in relation to a

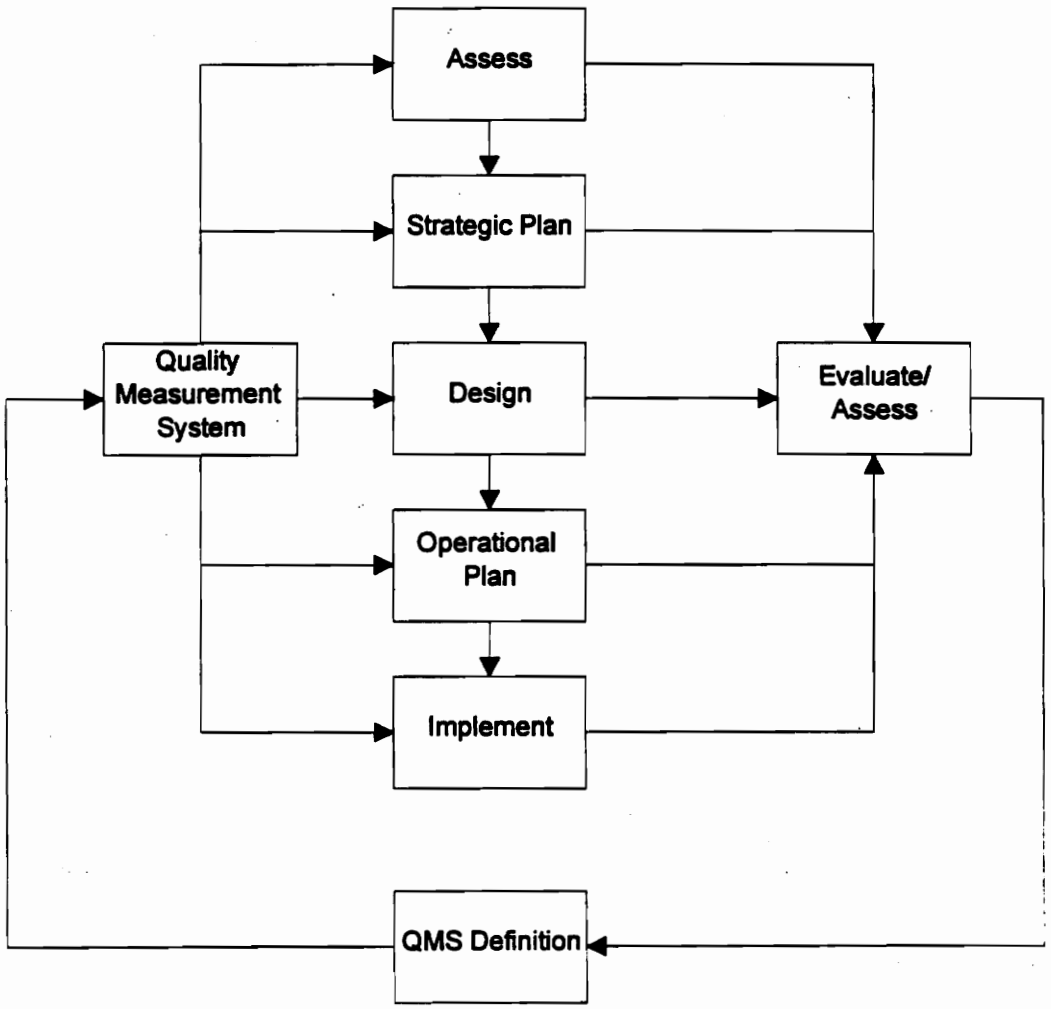


Figure 4. QMS Development

given standard. Equally important is an understanding of any limitations that may exist in achieving a particular standard. Such an understanding can be obtained through an assessment of an organization's quality management capabilities.

To begin an assessment, one must determine how an organization defines *quality*. Is quality determined by a product's conformance to specifications? Is it linked to specific product features or the presence or absence of certain attributes vis a vis competitors' services or products? How do customers define quality? Based on what is important to an organization, the organization must prepare a list of criteria that addresses all aspects of the functioning of its ideal QMS. Though such a list will serve to identify what a company wishes to look for in its QMS, it will not permit an organization to determine how well its criteria for system performance are actually being implemented. Only through measures - concrete and unambiguous, qualitative and quantitative - can an organization establish a base against which it can measure its growth or gains in quality management.

### 2.2.2 The Definition of Strategic and Operational Goals/Objectives

Both strategic and operational goals and objectives

must be established when developing a quality management system. These may be expressed in terms of the presence of certain performance-based criteria or the extent to which such criteria are present. Once again, measures are called for. Measures are needed to ensure that goals and objectives are expressed in quantifiable terms, e.g., the reduction of scrap and rework by 10% over a 6-month period.

Equally important as performance goals and objectives, is the need to plan for how these milestones will be achieved, i.e., over what period of time and to what degree. Strategic and operational plans can be potent maps for this work. In order to express plans in quantifiable terms, an organization again needs to utilize measures; to achieve a 10% reduction of scrap/rework, for example, a company might plan to spend 15% of its operational budget on education and training of its workforce. Quality-related measurement data obtained at an earlier time by an organization can serve as useful input for the organization's planning process.

### 2.2.3 The Design of a Quality Management System

The design of a QMS is ultimately expressed through an organized set of detailed specifications. Specifications that meet goals and objectives defined earlier by the organization must be developed. Such specifications may be expressed in terms of the presence of certain criteria and

the extent of their maturity. Here, again, measurement is key. Measures pertaining to quality performance criteria are critical in capturing the extent of the maturity of each of the criteria and hence, changes in the quality management system over time.

### 2.2.4 The Implementation of a Quality Management System/Design

When implementing a QMS, measures provide valuable feedback that enable an organization to quantify the extent to which it has achieved its goals.

## 2.3 ASSUMPTIONS

Any organization seeking to implement or enhance a QMS needs to begin with certain fundamental knowledge, attitudes and awarenesses regarding quality. In completing this research, it was assumed that such a body of knowledge is present within an organization. Specifically, assumptions were made concerning the approach of an organization's management in three areas: a) its basic understanding of the philosophy of Total Quality Management, b) its motivation for implementing TQM, and c) management's expectations for TQM within its organization.

### 2.3.1 Management's Understanding of and Commitment to TQM

1. Management must exhibit a full commitment to the philosophy and practices of quality management. It must be prepared to initiate the requisite changes and commit sufficient resources in bringing about the realization of a QMS system. This commitment must be made on a long-term basis, for a QMS (and its measurement) are not intended to fight fires only or fix problems that have erupted.

2. In order for TQM to flourish, an unambiguous definition of a QMS must be shared throughout an organization's culture. Working definitions of product or service quality, process quality, and quality management should exist (or be able to be developed) within an organization with little or no ambiguity in their meanings.

3. Managers and employees must be educated about QMS development, measurement principles, statistical evaluation approaches, and structured group processes. A spirit of cooperation between management and employees is key to using this particular body of knowledge and fully realizing TQM within a company.

Parties who participate in developing a questionnaire, for example, must be well-trained in the principles of TQM. They should be familiar with their work environment and able to focus on the problems of particular quality-related processes and activities in their group or department that require monitoring and/or improvement.

4. Management must view its employees and workers as its most valuable assets rather than dreaded liabilities. Management must accept responsibility for the development of its workers and employees [Dutta (1989)].

5. Management must welcome and facilitate stakeholders' participation in developing quality improvement plans. Stakeholders must share in some decision-making activities. Their active support is key.

6. It is not a simple task to develop and implement measures, compile statistical data, store, and then retrieve this information. Considerable time and resources are required for the systematic development of a QMS. Management and

stakeholders must demonstrate support for (or suggest that they will support) using and maintaining a measurement system. In the absence of expressed support and acknowledged responsibility for these efforts within an organization, continued advances in quality are unlikely.

### 2.3.2 Management's Motivation for Implementing TQM

1. Quality must be a corporate goal and a primary one.

2. Management's motivation must be the improvement of the QMS using accurate and complete information about process, product, and service attributes. Measurement for the sake of measurement alone cannot be an ultimate aim.

3. Measurement for the sake of control alone will be counterproductive to the quality goals of an organization. It must not be a motivating factor.

4. Changes within organizational structure must be viewed as possible if not imperative for the organization's continued financial health.

5. The customer is a forcing function for improvement.

This means that an organization must change from a producer-oriented system to a customer-oriented system [Sink (1989)].

6. External factors such as competition in the marketplace, or internal factors such as a high scrap rate, are other prime motivating factors for implementing or improving a QMS.

### 2.3.3 Management's Expectations for TQM Within Its Organization

1. Management must understand and be prepared to accept the cultural, behavioral and philosophical changes required to develop and further a QMS. Moreover, management must be willing to act on the information it learns about its quality-related practices and QMS performance.

2. Management must remember that resistance to change is inherent in all human activity. Resistance to a change in a QMS or to a new system can be eased by education, training and the use of incentives. It is also possible to break down resistance by choosing quality improvement projects on a pilot basis and posting early successes with these projects.

3. No matter how badly an organization might want to transform itself to some new order, management must recognize that it must continue doing business and, for the time being, do so in the way it knows best [Scholtes (1988), Part I].

4. Management must appreciate the well known truth that improvements in quality are a continuous process [Dutta (1989)].

# CHAPTER 3: REVIEW OF THE LITERATURE

## 3.1 A BRIEF HISTORY OF STRATEGIC QUALITY MANAGEMENT

When viewed historically, the modern quality movement may be broken into four eras. Blending with and building upon each other, the eras reflect periods of differing emphasis and effort by American businesses to ensure and promote quality [Garvin (1988)].

As observed by Garvin, the earliest "inspection era" was characterized by special emphasis on the detection of problems in products based on an item's conformance to specifications; a combination of final inspections and post-production adjustments were commonly used to ensure quality [GAO (1991); Garvin (1988)]. An era of statistical quality control beginning in the 1930s later added and emphasized advanced statistical and sampling methods - techniques to reduce the number of inspections. These methods also more efficiently controlled products' conformance to specifications. A third era followed in the 1950s in which organizations began to proactively coordinate between all departments in the production chain to prevent failures in quality. This period, one of quality assurance, expanded on the practices before it [Garvin (1988)].

Throughout each of these periods, organizations sought

Throughout each of these periods, organizations sought to control quality in a manner consistent with what was perceived as quality within their respective departments and corporate cultures. As described, this most commonly translated into efforts to control and limit product defects. Such efforts were typically relegated to specialized, lower-level departments. Rarely in the early periods of quality management did issues of quality assume strategic importance in the corporate boardroom. Equally rarely were customers solicited for their opinions or reactions to product or service quality [Pfau (1989); Garvin (1988)].

Over the past decade, however, a number of forces have driven changes in the quality-related attitudes and practices of American businesses. Increased foreign competition both here and abroad has compelled U.S. companies to distinguish themselves from a larger field. In particular, the emergence and successful penetration of postwar Japanese businesses into American auto and electronics markets in the late '70s and early '80s proved unequivocably the powers of superior quality and reliability to command market share and erode U.S. profits [Garvin (1988)]. American manufacturers took notice.

Government's increased vigilance of domestic products also awakened U.S. organizations. Recalls of defective or

unsafe products such as those made by the U.S. Consumer Product Safety Commission, Environmental Protection Agency, and National Highway Traffic Safety Administration, for example, showed companies - and continue to show companies - the all-too-painful cost of producing lesser quality and defective goods. A dramatic leap in product liability suits between 1974 and 1981 drained yet additional millions from U.S. corporate pockets, another cost for not producing quality [Garvin (1988)].

Collectively, such changes have given rise to what may be called a fourth era in the quality movement. In this newest period, issues of quality are no longer being left to technical inspectors and statistical printouts alone. A new philosophy has emerged that calls upon the power, ideas and responsibilities of the entire work force to make quality a competitive advantage, not simply a cost of business. Quality itself has been redefined; it has been pushed to center stage. The age of Strategic Quality Management (SQM) has arrived.

"Building quality in from the beginning ... making quality everyone's concern and responsibility." [Pfau (1989), p.17] This is Loren Pfau's view of Strategic Quality Management. It is an organizational process. It's "an approach for continuously improving the quality of goods and services delivered (by an organization) through the

participation of all levels and functions of the organization," explains Pfau [Pfau (1989), p.17]. Strategic Quality Management is proactive rather than reactive. "Companies should seek out and exploit opportunity for improvement; they should view this change as a natural continuous path of activity" [Pfau (1989), p.17].

Like previous eras, the newest emphasis on SQM includes many of the earlier lessons learned about quality. It differs, however, in several key respects. In this newest age, quality is more consistently defined with the needs and requirements of customers in mind. In fact, it has become customer-driven. Top-level management now more consistently takes full interest and/or participates in the management of quality. The subject commands the highest attention and commitment of leadership. Finally, the management of quality is more commonly included in the strategic planning process. Strategic Quality Management is today viewed as a competitive strategic weapon in the marketplace.

## 3.2 STRATEGIC QUALITY MANAGEMENT AND BUSINESS PERFORMANCE

Movement toward this expanded view of quality management has come for good reason. Apart from the obvious success of Japanese auto and electronic makers, a number of studies have documented significant benefits to U.S.

organizations willing to adjust their focus and adopt alternative practices in managing for continuous gains in quality [GAO (1991); Garvin (1988)]. A 1991 report by the U.S. Government Accounting Office (GAO), in particular, documents multiple performance payoffs for twenty American companies shown to have developed successful quality management strategies within their corporate cultures [GAO (1991)].

When allowed sufficient time to realize gains, the companies' achievements were measureable across four areas. Somewhat better employee relations were suggested by indicators such as employee satisfaction, improved attendance, improved safety and health, and decreased turnover. Operating procedures improved in a number of companies; these gains were reflected in reliability, timeliness of delivery, inventory turnover, cost savings, order processing times, product lead time, and reduced quality costs. Greater customer satisfaction was a third payoff. Fourth, companies saw valuable financial rewards: growth in market share, sales per employee, return on assets, and return on shares. Collectively, the changes allowed for improved productivity and profitability among the group [GAO (1991)].

Shared among the Total Quality Management programs reviewed in the GAO study were a number of common features.

Corporate attention, for example, was found to be strongly focused on customers: quality was customer-defined; companies took new approaches to customer feedback; internal customers commanded fresh recognition. Management was also found to lead the way in disseminating TQM values throughout the organizations: quality improvement was included in strategic and operational planning; companies planned and adopted systematic processes for continued measurement and evaluation of quality product/service; they used statistical process control techniques to review manufacturing processes to identify and eliminate defects; requisite changes were then promptly implemented [GAO (1991)].

A third feature common to the TQM programs was managements' actions authorizing and empowering employees to continuously improve key business processes: many companies implemented systems to address employee complaints and ideas; training programs encouraged quality-related skills and awareness among workers. Additionally, the organizations tended to practice fact-based decision-making. This was done in atmospheres with few formal and informal barriers among workers. Overall, corporate flexibility and responsiveness were heavily emphasized by management [GAO (1991)].

As suggested by the GAO findings and similar studies, efforts to improve quality have come to assume strategic

importance because they appear to make a difference in the organizational bottom line. Factors such as price, cost and productivity - standard measures of business performance - also affect the bottom line. Given this, an important question arises: How do improvements in quality affect the standard indicators of business performance? What is the relationship between continued revitalization of the quality of products or services and, say, product or service cost? price? Are the relationships predictive? Can they be measured?

Garvin analyzed such relationships in his work Managing Quality. Surprisingly, cost, price, productivity, profitability, advertising, and market share each were found to correlate with quality in complex, sometimes unpredictable ways. Empirical findings conflicted with theoretical projections. Under certain conditions, quality and price were positively correlated; at other times or in different industries, the two moved inversely to each other. Similar variability was seen with market share and other indicators.

Why, one could ask, should improvements in quality affect business performance indicators so (seemingly) inconsistently? Why should empirical findings belie theory or prove weaker than projected? According to Garvin, at least some of the answers rest with the multi-dimensional

nature of quality itself. Its facets are indeed many.

Quality involves questions of performance, features and reliability. It speaks to issues of conformance, durability, serviceability, aesthetics, and perceived quality [Garvin (1988)]. Who defines quality is as vital as the dimensions that are encompassed by it: is quality defined by manufacturing directors? Marketing managers? Consumers or CEOs? Dimensions of quality are both independent and interrelated; one dimension can improve at the expense of the other or in proportion to it. Each also is self-contained and distinct for a given product or service; a product or service may be high in quality for one element and low in another.

Such complexity necessarily confounds what might otherwise be a simple assessment of the relationship between continued quality improvement and standard business performance indicators. To the extent that many existing correlation studies reflexively view quality as a single dimension, they obscure the individual and unique impacts of quality's many dimensions on other business indicators, argues Garvin. Many studies, for example, relate quality to a single performance indicator without an appreciation for the host of other influences that can distort and alter the relationship. Correlation studies may also require analytical techniques different than those usually applied.

Garvin suggests, for instance, that when looking at quality and its relationships to price, multivariate statistics may yield more accurate modeling than other, traditional approaches that are less complete. Overall, a dearth of empirical studies limits the power of the existing research base to make predictive statements about the effects of improved quality on standard business performance indicators [Garvin (1988)].

However intricate its relationships, an understanding of the role of quality within an organizational model is vital. Given a thorough understanding of quality, one can more clearly define it - both on paper and operationally. This facilitates more accurate measurement. With full and accurate measurement, it then becomes probable that the effects of improved quality (in all its dimensions) on standard business performance indicators will be better correlated and fully appreciated.

## 3.3 FEATURES AND COMPONENTS OF "EXCELLENCE" IN QUALITY MANAGEMENT SYSTEMS

### 3.3.1 ENTERPRISE-LEVEL CRITERIA

In the current professional literature on quality, many articles and publications address what are believed to be

the key ingredients or critical components of excellence in quality management. Included in this literature are five documents that outline numerous criteria and evaluative procedures specific for *enterprise-level* activities of an organization's structure. The five documents lay a foundation of generic guidelines for defining quality management excellence, a foundation previously elucidated by Triantis, et. al. (1991a). Widely accepted within industry and government organizations, these documents are reviewed below.

The most widely accepted formal definition, perhaps, of what constitutes a total quality management company exists in the criteria for the Malcolm Baldrige National Quality Award [GAO (1991); Baldrige (1991)]. Given by the U.S. Commerce Department since 1988, criteria for the Baldrige Award were developed by the National Institute of Standards and Technology (NIST) to promote information sharing between American organizations regarding successful quality strategies. The guidelines are intended to be used as a basis for self-assessment by business, government agencies, health care organizations, and educational institutions pursuing quality excellence. According to the Baldrige Award scoring system, the most important criteria for total quality management are: customer-driven quality, quality results, human resource utilization, and quality assurance

of products and services.

A second document, the ISO Series 9000-9004, also offers comprehensive and detailed guidelines for quality excellence [ISO (1987)]. Produced by the International Standards Organization, criteria in this series are targeted at the manufacturing and service industries and their associated customers. The criteria focus clearly and concisely on elements needed to assure both internal quality management and external quality assurance; as such, the guidelines may be applied within an organization (during internal self-assessment evaluations) or extended to outside contractors and suppliers (in the form of contractual requirements). Because the scope and application of criteria in the ISO Series 9000-9004 are so well defined, the criteria can be readily operationalized when tailored to an individual application.

The 1990 President's Award for Quality and Productivity Improvement targets quality management within federal government agencies [Federal Quality Institute (1990)]. Criteria and scoring guidelines for the President's Award were developed to identify and recognize federal agencies that have become excellent examples of Total Quality Management. The criteria are intended to serve as a basis for routine self-assessment evaluations and on-site visits by federal examiners. Eight major elements are included in

the criteria set forth in this award: 1) top management leadership and support, 2) strategic planning, 3) focus on the customer, 4) employee training and recognition, 5) employee empowerment and teamwork, 6) measurement and analysis, 7) quality assurance, and 8) quality and productivity improvement results. As reflected in the President's Award scoring guidelines, customer satisfaction, quality results, human resource utilization, and quality assurance of products and services are key determinants of excellence in a quality management.

The Institute for Industrial Engineers (IIE) has established its own body of criteria for denoting gains in quality [IIE (1990)]. Unlike the criteria previously discussed, guidelines for the IIE Award incorporate factors of productivity and cost. Six criteria are considered significant by the IIE: strategic and business planning, leadership and management in productivity and quality, management by data, productivity and quality management, productivity and quality training and continuing education, measurement of results. All criteria are targeted at the manufacturing and service industries. Though scoring guidelines are not included, the presence or absence of the elements is intended to identify organizations that have accomplished significant, measurable and observable achievements in increased productivity, reduced human

drudgery, and improved quality. The IIE criteria are not sufficiently comprehensive or detailed to be used alone in assessing or implementing a TQM program.

A fifth set of quality-related, enterprise-specific criteria for quality excellence are those used to judge recipients of the Virginia U.S. Senate Award [Virginia (1990)]. Like the President's Award, the Senate Award honors American organizations with particularly effective productivity and quality improvement efforts. Twelve criteria form the evaluation basis for this award, given to private manufacturing and service industries as well as local, state, and federal agencies. Criteria include quality of (an organization's) application, innovation and/or originality, transferability of techniques employed, willingness to share results, comprehensiveness, commitment and involvment by top management, measurement and evaluation process, employee involvement, long-range plan for constant improvement, customer focus/service focus, results, and the planning process.

### 3.3.2 PROCESS-LEVEL CRITERIA

In contrast to the above criteria, other similarly well-regarded guidelines for evaluating Total Quality Management concentrate on specific key processes of an organization rather than the performance of an enterprise as

a whole. *Process-level* functions such as production/service processes and management processes are specifically targeted. Certain organizational elements or units are emphasized as well, e.g., programs, cost and profit centers, and particular departments. Within the professional literature, five frequently referenced documents outline criteria specific for assessing Total Quality Management with regard to such process-level functions. Widely recognized within the field, these documents are reviewed below.

The ANSI/ASQC Q90-Q94 Series Standards is identical to the ISO 9000-9004 Series discussed earlier. It is also most comprehensive [ANSI/ASQC (1987)]. Like the ISO Series, the ANSI Standards focus clearly and concisely on elements needed to assure both internal quality management and external quality assurance. The standards address both process details and management functions. They can be applied to any organization or organizational unit regardless of its involvement in the contracting process.

According to the ANSI/ASQC Standards, the main elements of a world-class organization implementing Total Quality Management include: a quality management system (itself), quality costs, quality in marketing, quality in specification and design, quality in procurement, quality in production, product verification, control of measuring and

test equipment, nonconformity, corrective action, handling and post-production operations, quality documentation, and records, personnel, and product safety and liability. Despite these rather exhaustive criteria, "continuous" enhancement of the Quality Management System itself is not a stated objective of the ANSI/ASQC Standards. Though the importance of the product life-cycle in a TQM program is strongly emphasized, quality leadership, results, and quality-related information systems are not.

Criteria set forth in MIL-Q-9858A provide contractors for the Department of Defense (DOD) with guidelines for process-related quality management. These criteria offer specifications for establishing a quality management program when it may be required for a given contract. Within the MIL-Q-9858A criteria, the definition of quality is implied to be compliance with contract requirements; conformance with DOD-mandated specifications is also implied. Five elements are defined as key: quality program management, facilities and standards, control of purchases, manufacturing control, and coordinated government/contractor actions. In general, management functions are emphasized less than process-related elements. Missing from the MIL-Q-9858A criteria are certain critical elements including human resource utilization, productivity management, and strategic planning and its relationship to quality planning.

A third benchmark for process-level quality management can be found within the aerospace industry in the NASA Quality and Excellence Award [NASA (1991)]. Though no longer active, this award gave NASA and its contractors a means of evaluating contractor quality so that it might be publicly acknowledged. According to award criteria, the major elements of a process quality management program are customer satisfaction, quality assurance, and productivity. Less detail was offered for those criteria dealing with process control and measurement, and issues of testing quality.

Vendors and suppliers are the target of the Ford Motor Company Vendor Evaluation Guidelines [Ford (1990)]. Through use of a questionnaire, the Ford Motor Guidelines provide a procedure for measuring and evaluating subcontractors and vendors to assure their effective control of the quality of products and services being procured. Significant process-level quality management criteria include: planning for quality, statistical methods, quality auditing, documentation, facilities/equipment, customer concerns, and in-process and outgoing quality control. These criteria emphasize the quality process control elements; lesser attention is paid to the management elements that support the process control activities. Criteria also are lacking regarding quality costs and information sharing.

The fifth document is the DOD 5000.51-G TQM Guide [DOD (1990)]. It is intended for use by executive management to determine the status of the implementation or enhancement of Total Quality Management within a DOD organizational element. The Guidelines also serve to introduce to procurement professionals, operating management, contractor personnel, and executive management to specific techniqes and process enhancements during each cyle of the implementation/enhancement process. Primary factors for quality management as viewed by the DOD Guide include: top management commitment, obsession with excellence, an organization that is customer driven, customer satisfaction, training, employee involvement, use of incentives, and the use of tools.

## 3.4 DATABASE MODELING FOR QUALITY MANAGEMENT SYSTEMS

A number of resources enabled this author to explore the basic concepts of entity-relationship (E/R) modeling, its applications and its advantages for QMS measurement. Database Modeling & Design: The E/R Approach Entity Relationship Model by Toby Teorey offers significant background information concerning database modeling. Another valuable resource is Database Analysis and Design by

I.T. Hawryszkiewycz. Detailed concepts of the E/R model, its use, implemention and benefits are further discussed in Chapter 6.

# CHAPTER 4: PERFORMANCE MEASURES OF A QUALITY MANAGEMENT SYSTEM

## 4.1 OBJECTIVES

This Chapter presents guidelines for measuring quality that may be used by any organization to assess, monitor and improve its quality management capabilities. The guidelines specify a procedure for defining measures of quality as well as an actual set of generic quality measures that may be tailored to the specific, unique needs of organizations in the manufacturing and service industries. Both the measurement methodology and set of measures apply to enterprise-level (or operational) and process-level (or strategic) views of an organization. Both also address subjective and objective criteria of a quality management system.

## 4.2 INTRODUCTION TO MEASURES AND MEASUREMENT SYSTEMS

Any object, process, or being in this world has attributes that describe it. Height and weight, for example, are two attributes of a human being. When a scale is assigned to an attribute - such as inches/feet to height, or pounds/ounces to weight - the attribute becomes

countable; it becomes quantifiable. Together, both attribute and scale become a measure - in this case, a measure of tallness or a measure of heaviness. Innumerable measures exist in daily life: compensation expressed in dollars; response of an ambulance expressed in minutes; distance counted in miles; noise measured in decibels. All reflect measures and their organization of the world around us.

In the broadest sense, measures may be thought of as hard or soft. *Hard, or objective measures*, are concrete in nature. The weight of a product, the number of employees, or the time to process information, each represent hard measures - measures of weight, number and time. These, and other similar measures, are directly countable. *Soft measures*, by contrast, are subjective in nature. They are intangible. They focus on attitudes, perceptions, and feelings - qualitative factors - that are not directly measureable by physical or linear scales. Thanks to industrial psychologists, specialized measurement techniques for counting the intangible features of attitudes and perceptions are well articulated [Hayes (1992)]. When appropriate scales are employed, assessment of qualitative factors can lead to reliable, valid measures of human actions and values.

Worthwhile measurement systems, however, don't just

appear. They must be systematically developed and maintained [Sink (1989)]. They demand time, attention and resources. They require followup. The "plan-do-check-act" cycle developed by Deming, in fact, is appropriately applied to the needs of a measurement system, as like any other system, if an organization's efforts at measurement are going to further its objectives in achieving continuous gains in quality.

## 4.3 EFFECTIVE MEASURES AND MEASUREMENT SYSTEMS

Do "good" measures have anything in common? What makes a measure or measurement system effective? Simple, unambiguous, "user-friendly" measures (and systems) are most useful. This, of course, assumes that they are applied to appropriate behaviors and processes within an organization. Measures and systems that are directly applicable to current processes are deemed especially practical as this makes them more likely to be adopted. Measures (and systems) that can be readily updated or modified in different situations gain added power [Triantis, et. al. (1993)].

Effective, strong measures share other commonalities. Since the collection, storage, retrieval, and analysis of data that support measures (and systems) are on-going processes capable of consuming tremendous resources,

measures (and measurement systems) that minimize the costs of these needs are favored. The most effective designs for measures (and systems) encourage the participation of employees at all skill levels given only little training/education; this increases ownership of measures and helps to lower resistance from the participating parties. The best quality-related measures and measurement systems are consistent and thoroughly integrated with the quality measurement objectives of the organization and its vision of quality management development.

In creating measures, the following design criteria are important to be kept in mind. *Valid* measures specify or actually measure what is purported to be measured; invalid measures measure something other than what is intended and are rendered functionally useless. Measures that are *reliable* ensure that errors in the measurement process are minimized over time or at least kept consistent; reliable measures provide consistently valid results. *Accurate and precise* measures, those which indicate the "true" state of a phenomenon, enhance overall validity and reliability [Sink (1989)].

Other features give measures added power. Measures that are *specific and unique* facilitate a "cleaner" look at a process or phenomenon; unless preplanned and accounted for, measures that overlap or are redundant have the

potential to muddy an organizational picture with ambiguities. Making measures *complete and exhaustive* helps to ensure that all variables within a system are included. [Sink (1989)].

When devising a measurement plan to assess ongoing performance of a quality management system, it should also be remembered that "quality" has both objective and subjective attributes. As such, objective and subjective measures are called for. Objective measures can be used to capture such things as frequency of equipment inspections, number of employees trained in quality control procedures, or the cost of warranty claims, etc. Subjective measures can be employed to capture the attitudes and morale of employees or the perceptions of internal and external customers. Only when both hard and soft measures are fully utilized can all of the varied mechanical and human elements inherent in a QMS be accounted for when assessing changes in performance over time.

## 4.4 SCOPE OF CHAPTER

This Chapter is more than mere academic exercise. The methodology and measures put forth are designed to be utilized in any organization within the government or private sector, service or manufacturing industries. An

organization may utilize the information to support its development of a new QMS or the maintenance and enhancement of an existing one. Since the measures reflect enterprise- and process- views of an organization, it is possible, with them, to measure both the operational and strategic components of an organization's approach to continued quality improvement.

In addition, the methodology and generic measures are quite flexible. The measures may be applied within an organization to develop, maintain and improve a quality management system as just stated. They may also be used to support other organizational systems, for example an employee reward, bonus, or recognition structure, or a training and development process. When used external to an organization, the methodology and measures can be applied to parties such as suppliers and vendors whose products or services have significant consequences for the organization. For example, in the process of contracting with new vendors, an organization may utilize the measures to clarify the operating parameters for its vendors and to assess their quality management capabilities.

## 4.5 METHODOLOGY FOR DEFINING MEASURES FOR A QMS

To begin, the building blocks of each module of a QMS

were analyzed individually. An extensive literature search was completed to identify significant numbers of additional elements that were applicable to many of the modules. The relationships between each element and its particular, unique influence(s) on quality were further considered in detail; attributes of each element were illuminated that might reflect or influence the role of the element within a quality system. Based on this analysis, generic measures were evenutally formulated and articulated in writing that were thought to best capture the various relationships, effects and contributions of the elements to the quality management system as a whole.

At each step in formulating measures, the following questions were considered and applied:

a) Will the measure have meaning to a management team?
b) How realistic is the measure? How likely is it that it will "work?"
c) Can the measure be worded simply and in unambiguous terms?
d) If a ratio is necessary - for example between inputs and outputs - can it be properly defined and consistently applied?
e) Will the value of the measure justify the cost required to collect, store, retrieve and portray its data?
f) Does the measure support the overall objectives and

philosophy of Total Quality Management? [Triantis et. al., (1993)]

When applied, the above methodology gave rise to a set of measures that were quantitative and qualitative in nature. Appropriate units were applied to those that were quantitative and an appropriate scale for qualitative measures developed; this is further discussed in Chapter 5. Measures that were found to apply equally well to more than one module were repeated as needed in each module so that every module might stand alone. These common measures are cross-referenced with each other for easy identification.

The set of prototype generic measures was developed for ten out of the thirty-seven modules of a quality management system. Figure 5 identifies the ten specific modules.[2] The set of prototype measures is found in Appendix B of this thesis. All of the elements (and their associated modules) reflect a mix of enterprise-level and process-level behaviors within an organization.

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[2] Because cross references for the common measures in these selected modules sometimes refer to measures/modules not included in this Chapter, the reader is encouraged to review the full set of measures found in "Document E" by Triantis, et. al., 1993, "Report on Process and Strategic Based Quality Measurement Guidelines for Quality Management System Development of Hardware Electronic Manufacturing Facilities."

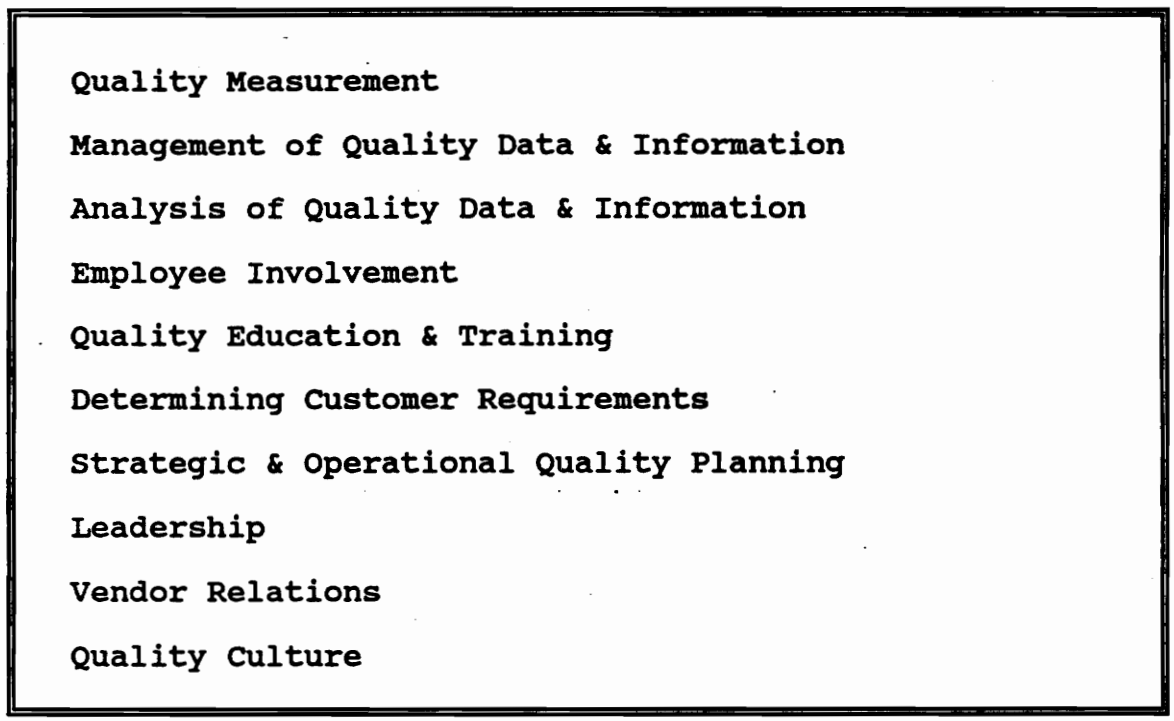


**Figure 5. Ten Modules For Which Prototype Measures Are Developed**

## 4.6 ORGANIZATION OF PROTOTYPE MEASURES

Generic measures created in the work of this Chapter are grouped (in Appendix B) according to the ten modules to which they apply. Definitions for the individual measures are stated along with the definitions for each module. Within each set of measures for a module, measures that capture particular trends in the overall performance of the module are regrouped separately at the end.

## 4.7 CONCLUSION

The primary objective of this Chapter was to develop a methodology for identifying generic performance measures for a QMS based on the operational definition of a QMS. Prototype measures were also to be created to illustrate this methodology. Both objectives were achieved.

The methodology works well to define generic measures that reflect both qualitative and quantitative aspects of QMS activity. Through its application, the author created a substantial number of unique measures able to capture changes in QMS activity. Measures are extensive, user-friendly, and applicable to any work environment in the business or government sectors.

Given such a set of generic measures, further work is now needed. How are the measures to be operationalized within an organization? What is needed in order to actually

gather data with these measures? The next Chapter addresses these questions. In it, a methodology is presented and a questionnaire constructed for collecting both qualitative and quantitative data. The methodology recognizes that the operationalization of performance measures within an organization must be specific for the particular organization's work environment. It recognizes, therefore, that the generic measures developed in this Chapter must be tailored for some "test" work environment for their full application.

# CHAPTER 5: COLLECTING MEASUREMENT DATA

## 5.1 OBJECTIVES

This Chapter presents a methodology for developing a questionnaire to collect data for objective and subjective performance measures of a quality management system. The methodology is intended to be applicable to all measures of a QMS. Keeping with the philosophy of Total Quality Management, the methodology provides for direct contributions from an organization's stakeholders.

Also included in this research is a prototype questionnaire. The questionnaire has been developed using the above methodology and can be found in Appendix C. It allows for the collection of measurement data specific for the Vendor/Contractor Relations module outlined in Chapter 3 of this thesis - just one of the thirty-seven modules that comprise a quality management system. It is not the objective of this Chapter to evaluate the statistical merits of the prototype questionnaire.

## 5.2 INTRODUCTION TO QUESTIONNAIRES/SURVEY TOOLS

A questionnaire can be a versatile and valuable tool for collecting data. It can be adapted to gather

information regarding objective and subjective measures both internal or external to a work environment. It can be employed in any service or manufacturing environment. Unlike data for objective measures that are readily quantifiable through concrete vehicles such as weighing scales or linear scales, data for subjective measures are less readily obtained. Measures of stakeholders' perceptions and attitudes, for example, or workers' perceptions of the quality of their work life are not easily quantified with objective scales. Nonetheless, such data can be collected through use of a well-developed questionnaire. Moreover, they are vital to a comprehensive understanding of the quality of any service, product or system.

In Measuring Customer Satisfaction, Hayes presents a methodology for designing and developing questionnaires for surveying a spectrum of issues concerning customers. What are customers' requirements regarding certain products and services? Are customers satisfied with the services and products they've received? What satisfies them? What dissatisfies them? Are there specific attitudes and perceptions that customers hold regarding products/services? What do they value? These questions and more can be explored and their responses counted through use of an appropriate questionnaire.

As used by Hayes, the term *customer* applies to both internal and external parties. Groups or individuals within an organization who receive services or products directly or indirectly can be thought of as *internal customers*. *External customers* are those beyond the organization - groups or individuals who are affected by products or services. Since all such customers are affected by the organizational systems that serve them, all maintain personal attitudes, perceptions and beliefs about the systems - indicators that may be measured. As a quality management system is but one system within an organization, Hayes' methodology may be adapted to obtain qualitative and quantitative information about a quality management system that serves all stakeholders in an organization.

## 5.3 SCOPE OF CHAPTER

The methodology in this Chapter can be used to develop a survey tool for gathering performance-related data internal or external to any organization within the manufacturing or service industries in both the private or government sectors. Questionnaires derived from the methodology may be used to gather information in support of measures that evaluate strategic components such as leadership or strategic planning. Survey tools also can be

adapted for collecting data regarding operational components of a quality management system such as calibration and quality control. Beyond quality measurement, the methodology may be adapted to gather information regarding any performance-related criteria of an organization.

## 5.4 QUESTIONNAIRE RELIABILITY AND VALIDITY

At least one question invariably rises when adopting a questionnaire or survey to gather qualitative and quantitative information: How well does the questionnaire do what it says? Can one rely on such a tool to obtain true data regarding measures concerning quality?

*Reliability* and *validity* are two important criteria by which to evaluate a questionnaire's or survey's measurement. The term reliability refers to the degree to which scores obtained from a questionnaire - the "observed" scores" - are systematically related to some underlying "true" score. If results are reliable, observed scores can be assumed to be free from random error. In the case of QMS measurement, questionnaires with high reliability will distinguish between varying levels of quality system performance better than those with low reliability. They also make it more likely that one will find significant relationships between variables that are truly related to each other [Hayes

(1992)].

Three types of reliability are commonly spoken of: test-retest reliability, equivalent form reliability, and internal consistency [Hayes (1992)]. Reliability as defined by the internal consistency of a questionnaire concerns us most.[3] In addition, two elements can influence the reliability of a questionnaire: number of question items and the variability of questionnaire respondents. The more numerous a questionnaire's items or queries, the more reliable its findings. Similarly, the more heterogeneous the sample of respondents in terms of its perceptions and views, the more reliable the questionnaire's results [Hayes (1992)]. As previously mentioned, a measure of the reliability of the prototype questionnaire put forth in this thesis is beyond the scope of this research.

A second criteria by which to evaluate the merits of a survey or questionaire is through its *validity*. Validity refers to the degree to which a questionnaire's scale measures what it is designed to measure, or the degree to which evidence supports the inference(s) made from scores derived from a questionnaire's measures. Although one might

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[3] A full discussion of these general forms of reliability is beyond the scope of this investigation. The reader is referred to the following textbooks: Anastasi, 1988; Brown, 1983; Guion, 1965; and Gulliksen, 1987 [Hayes (1992), p.32].

have a highly reliable questionnaire, it is still important to question what an observed score actually indicates. Although a questionnaire may be highly reliable in distinguishing quality performance along some underlying continuum, for example, one would still want to ensure that the continuum is the correct one. As with reliability, the measure of the validity of the prototype questionnaire developed in this Chapter is beyond the scope of this research.

## 5.5 QUESTIONNAIRE RESPONSE FORMATS AND SCALES

Once designed, all questionnaires call for responses from those who are surveyed. The way(s) in which an individual may respond to a questionnaire are varied. They are determined by a particular "response format." Several response formats or scaling methods have been developed to collect subjective information. Among the most common are the following:

a) Checklist format [Hayes (1992)]

b) Likert scaling method [Likert (1932); Hayes (1992)]

c) Equal-appearing intervals [Hayes (1992)]

d) Scalogram approach [Guttman (1950); Hayes (1992)]

The checklist format is a simple yes-no scale that can quantify the number of positive or negative attributes of a

service, product or process.[4] R.A. Likert developed a response format using a five-point scale. This type of scale represents a bipolar continuum defined so that the lower end represents a negative response and the upper end reflects a positive response. With a neutral point in the middle, the scale's five-point gradations allow respondents to express opinions in varying degrees. Three sample Likert scales are presented below:

Agree-Disagree Continuum

| Strongly Disagree | Disagree | Neither Agree Nor Disagree | Agree | Strongly Agree |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |

Dissatisfied-Satisfied Continuum

| Very Dissatisfied | Dissatisfied | Neither Satisfied Nor Dissatisfied | Satisfied | Very Satisfied |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |

[4] "Instances" for measures used with this type of format are written as satisfaction items.

Poor-Good Continuum

| Very Poor | Poor | Neither Poor Nor Good | Good | Very Good |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |

The equal-appearing interval response format and the scalogram approach are more laborious scaling methods than that developed by Likert [Hayes (1992)]. These are not further reviewed in this Chapter.

The Likert response scale has several merits. Less restrictive than a simple yes-no checklist, it permits greater variability in response. This increased variability has been shown statistically to be more reliable than a two- or three-point scale such as a yes-no checklist. The scale has also been tested extensively by others and shown to be more reliable using fewer (questionnaire) items than the Thurstone or Guttman scaling approaches. It has also been shown (statistically) that scales having more than five points (as the Likert scales call for) offer little additional incremental value since their reliability eventually levels off [Hayes (1992)].

## 5.6 METHODOLOGY FOR DEVELOPING A QUESTIONNAIRE TO COLLECT DATA FOR PERFORMANCE MEASURES

As depicted in Figure 6, the development of a questionnaire was essentially a three-stage process. Stage I, partially completed in Chapter 4, is completed in this chapter as described below. The work of Stage II is also outlined in this chapter. Stage III lies beyond the scope of this research.

### 5.6.1 STAGE I: DEVELOPMENT OF QUALITATIVE & QUANTITATIVE MEASURES WITH OPERATIONAL DEFINITIONS FOR A PARTICULAR WORK ENVIRONMENT (See Figure 7)

#### 5.6.1.1 Define and Develop Generic Measures

A) Determine what must be measured in a quality management system to obtain a comprehensive view of how well the system is functioning, i.e., Ask what features are most salient or important to the continued functioning of the system.

B) Determine what must be measured to determine the weaknesses and strengths of a system as they are perceived by an organization's stakeholders.

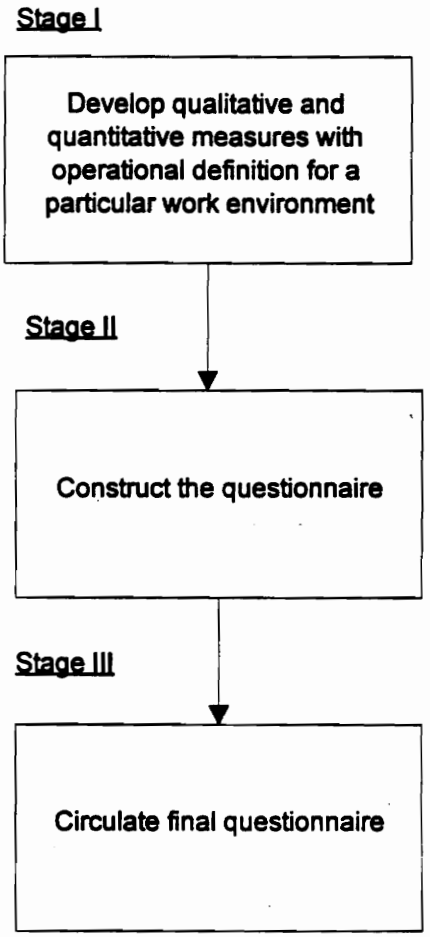


Figure 6. Methodology for Development of Questionnaire

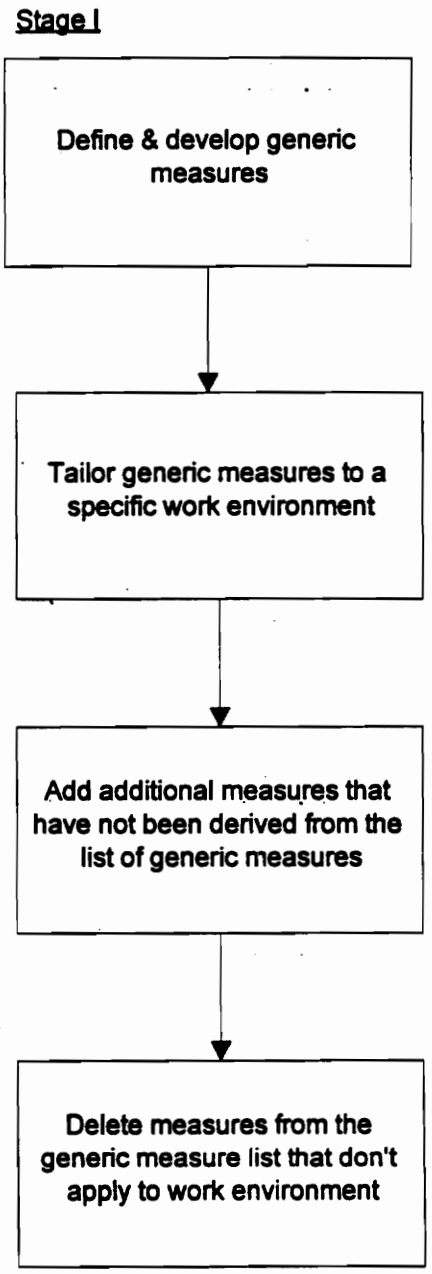


Figure 7. Developing Measures for a Particular Environment

### 5.6.1.2 Tailor Generic Measures to a Specific Circumstance, Work Environment or Industry

A) Highlight each measure and define it within the context of a particular work environment and/or industry.

Example 1: A generic definition of "maintainability" is: "The ease with which preventive and corrective maintenance can be achieved on a product" [Triantis, et. al. (1993)].

A definition of "maintainability" that is unique for, say, a product in the software industry might be: "The effort required to find and correct an error in operational programs."

Example 2: A generic definition of "reliability" is: "The probability that a product will operate after "t" hours of use [Triantis, et. al. (1993)].

A definition specific for a product in the software industry might be: "The extent to which programs perform intended functions

with precision."

B) Identify examples of processes or activities unique to the environment that might be measured. Such "instances," or "items" will serve as "operational definitions" and are pivotal in determining the way that each measure is quantified.

Example 1: Two instances of maintainability within the software industry might be: a) "Locating an error in the operational program is easy." b) "Fixing an error in the operational program is easy."

Example 2: Two instances of reliability within the software industry could be: a) "For the past 10 years, the software has performed functions accurately." b) "The software allows the operator to perform functions with precision."

In some cases, a series of multiple statements will most fully describe the activity being measured. The statements may describe a specific process or refer to a specific task performed by a person associated with the

process. Specific examples of a service or product may describe either a positive or negative performance of the service or product. Statements that describe a measure and seem redundant should be combined. The following rules (and examples) should be applied when developing operational measures:

Rule: Make "instances" concise. Eliminate superfluous words so that a final survey tool is easily read and understood.

Example (Poor): The contractor seemed to act in a very personable manner to me when I asked for a meeting.

(Better): The contractor was very personable.

Rule: To avoid equivocal responses, make "instances" precise and unambiguous.

Example (Poor): The service provided by the contractor's maintenance crew was good.

(Better): The service took a short time.
The service providers were friendly.

Rule: Have each "instance" contain only one thought so that a respondent is not forced to summarize

his or her reactions to two or more ideas at once.

Example (Poor): The contractor accommodated the buyer's specifications and took a long time to deliver.

(Better): The contractor met the buyer's specifications.

The contractor failed to meet its deadline for delivery.

Rule: Use no double negatives when developing "instances."

Example (Poor): The products were never not tested as contractually required.

(Better): The products were always tested.

C) Add any additional measures pertaining to the work environment not already included in a list of generic measures. Include definitions and examples.

D) Delete those measures that exist in the generic list that do not apply or are not needed in the list of specific measures.

Steps A-D are best completed with the assistance of experts/consultants and stakeholders themselves. Because of his or her unique expertise, an expert or consultant may draw on a number of resources to tailor generic measures to

a specific industry. He or she may draw from information in scientific, professional or trade journals, independent studies of the service or product and processes of a given industry. He or she may also rely on his/her professional knowledge, judgment, and experience with the practices of an industry.

Stakeholders can be tapped as well. Through structured interviews, both internal or external customers of the products/services/processes in question can be asked to select and define measures from a generic list and provide examples (for measures) from their own work environment. Since stakeholders are most aware of their own requirements for quality, it can be especially fruitful to solicit ideas and opinions from them. Involving stakeholders also provides a way to learn of specific, sometimes unique, examples from the customers' environment and organization that may help to clarify certain measures, thereby enhancing their value.

Certain points are useful to remember when interviewing stakeholders. Interviews may be conducted equally effectively with individuals or groups. Stakeholders participating in the process should be internal or external customers who have received some products or services from the system and have interactions with providers. Interviewees should be knowledgeable in the philosophy and

practices of quality management. The interview process is especially efficient when group sizes are limited to three to five participants; this way, deficient information from one interviewee may be offset by information from another, and the spectrum of customer requirements can be better represented.

When calling on stakeholders directly, customers' true requirements for quality products/services are rarely overlooked or misunderstood. Measures that a consultant or expert may identify as pertinent or valuable, for example, may be readily dismissed by a group of stakeholders; perceptions of an outsider can be far from those who are on the inside - persons who deal with differences in quality every day. In addition, feedback from stakeholders can often identify instances of product/service performance that may reflect the overall condition of a quality management system within an organization.

At the conclusion of Stage I, the survey developer will have generated a pool of possible measures that may reasonably be applied to a specific industry.

### 5.6.2 STAGE II: CONSTRUCTION OF A QUESTIONNAIRE OR SURVEY

(see Figure 8)

In order to construct a final questionnaire/survey, selected measures and their related "instances" must be

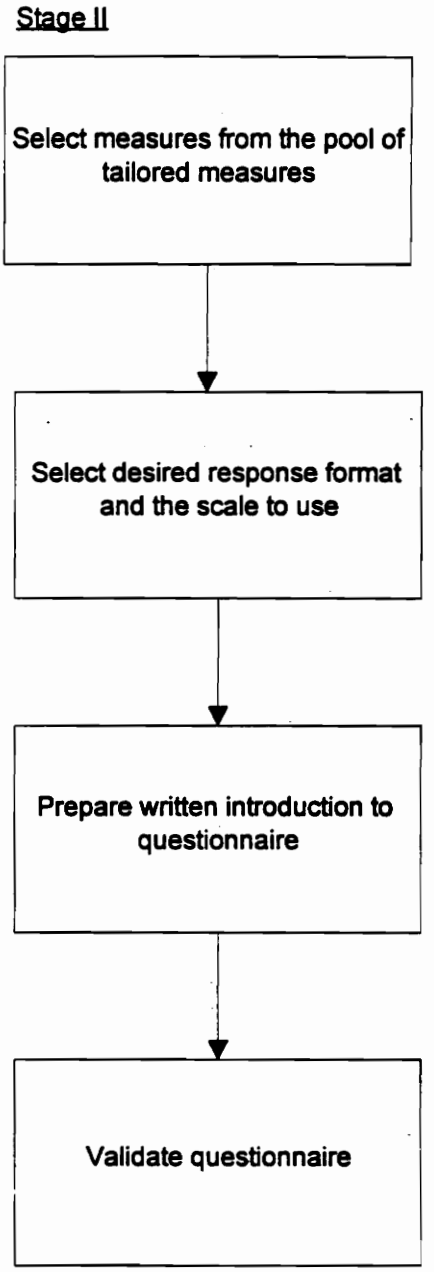


Figure 8. Construction of Questionnaire

integrated with appropriate scaling procedures. An introduction also must be written for the questionnaire. The tool can then be validated.

5.6.2.1 Select (Tailored) Measures for A Questionnaire

A) From the pool of potential measures and operational definitions, select those that best reflect the continued performance of a given module.

B) Select measures based on the following considerations: accuracy/reliability; relevance to the objective(s) of the questionnaire; amount of available study time; number of intended survey respondents; available budget.

5.6.2.2 Select Desired Response Format

The choice of a response format determines how customers can respond to a questionnaire and, ultimately, how data shall be quantified and used. In selecting a response format, the following should be considered:

What degree of understanding is sought? Is it sufficient to know simply that a particular attribute or feature of a service, product or process is present or absent? If yes, a checklist format may be the simplest, most effective to use. If it is important to know more than the presence or absence of an attribute, that is, if one

needs to know the degree to which an attribute is present or absent, a five-point Likert scale is recommended. Other scales may be applicable as well but are not discussed in detail in this thesis.

When selecting one or another Likert scale, the following should be kept in mind: a) The Agree-Disagree continuum is best used with satisfaction-related items that are declarative in nature and reflect specific good or bad aspects of a service or product; b) The Dissatisfaction-Satisfaction continuum is appropriate for items that reflect specific aspects of a service or product; the items need to be stated in rather neutral terms; c) The Poor-Good continuum is appropriate for items that reflect specific aspects of a service or product; these items need to be stated in rather neutral terms.

5.6.2.3 Prepare Written Introduction To Questionnaire

A) Explain the purpose of the questionnaire and give instructions for how to complete it. If and when similar items are included, explain that this is for reasons of accuracy.

B) Explain how the data will be used, but be careful not to say something that may influence questionnaire responses.

C) Keep instructions brief, simple, and understandable.

5.6.2.4 Validate Questionnaire Tool

A) Test the final tool with a small group of respondents as regards the following: clarity of purpose; instructions and content; applicability to the respondents; relevance to survey objective; and length of questionnaire.

5.6.3 STAGE III: CIRCULATION OF FINAL QUESTIONNAIRE

## 5.7 DEVELOPMENT OF PROTOTYPE QUESTIONNAIRE

### 5.7.1 STAGE I

In this research, generic measures developed earlier and outlined in Chapter 4 for the Vendor/Contractor Relations module (of a QMS) were tailored to the needs of a specific environment - "Organization Delta" ("Delta"). The methodology outlined above was applied and tested.

Both experts/consultants and stakeholders were involved in the process. Over a period of two years, a group of selected experts/consultants referenced literature pertaining to Delta's industry and held discussions with Delta's employees. This conferred considerable knowledge

and experience with Delta's work environment that enabled the group to assist in tailoring generic measures and naming instances appropriate for each.

A structured interview was then used to involve the stakeholders. All interviewees were asked to read the measures and definitions provided in the set of generic measures. By group consensus, measures that were thought to reflect or relate to the same issues of quality (according to the work environment at Delta) were grouped in a logical manner. The measures were also assigned priority. Each interviewee was asked to enhance or modify the definitions of each measure so that they better applied to his or her particular work environment. Although the suggested changes and modifications were to be recorded on separate note pads provided to each individual, *Delta* employees found the generic definitions fully acceptable and offered no modifications.

All interviewees were next asked to record (on their pads) as many examples or "instances" for the measures as they could for their respective work environments. The respondents were instructed to give specific examples of product, service, process, and management quality. They were also asked to structure their examples in such a way as to reflect specific good or bad aspects of the activities or behaviors. (This created instances for measures as

"satisfaction items.") General statements such as "Service was good/bad," or "The representative's behaviour was nice or unpleasant" were discouraged. Upon discussion, the few definitions and examples contributed by *Delta* employees through the above process were consolidated. Additional instances identified by this author were used to supplement the group's effort.

### 5.7.2 STAGE II

The instances developed in Stage I were re-reviewed by the author. All were retained for final use in a questionnaire.

The Likert scale was next chosen as the most suitable response format for gathering measurement data. Less restrictive than a simple yes-no checklist, the scale provides for greater variability in response. With it, stakeholders responding to various instances of product, service, or process-related quality would be able to indicate a spectrum of opinion about their environment and in more precise fashion. Since in order to measure system performance over time, one must gather information about a system at point "A" and compare it with information gathered (later) at point "B," the variability afforded by the Likert scale would allow this author to more closely monitor and measure changes in system performance. In short, the Likert

scale offered maximum utility in analyzing Vendor/Contractor behaviors and activities.

Of the different types of Likert scales, the agree-disagree continuum was the one selected. This choice necessarily followed from the author's earlier decision to use satisfaction-styled items to describe instances for measures. Had either of the other continuua for Likert scales been selected such as a dissatisfied-satisfied continuum or the poor-good continuum, instances (for measures) would have to have been expressed in neutral terms.

To conclude, a brief introduction was written for the questionnaire. This stated the purpose of the tool and instructed respondents in how to complete the questions. A page preceding the body of the questionnaire was also prepared for accommodating particular identifying information about the questionnaire itself, the date of its completion, the vendor who circulates it, and the customer (respondent) completing it. The final questionnaire was returned to the group *Delta* for their review and reaction. Members of the group concurred positively regarding the questionnaire's content and relevance.

## 5.8 ORGANIZATION OF MEASURES WITHIN PROTOTYPE QUESTIONNAIRE

The measures listed in the prototype questionnaire are

not listed randomly. Measures identified by *Delta* employees as similar or alike were first grouped together as a set. The sets were organized into "Parts" and these "Parts" ordered within the survey according to their relative importance for the unique Vendor/Contractor environment at *Delta*; this importance was determined by *Delta*'s working group. (Measures in Part I of the survey were deemed the most significant for the organization. Measures in Parts II, III, IV, etc. follow in order of their importance.) Within each Part, measures are numbered with arabic numerals, e.g. measures #1, #18 and #19 comprise Part I. These numbers correspond to the numbers used in the original list of measures for the Vendor/Contractor module (found in Appendix A). Letters a, b, c, etc. in the questionnaire represent the "instances" for each group of measures.

## 5.9 CONCLUSION

In this Chapter, the author accomplishes the second objective of this research project: to develop a methodology for creating a survey tool to collect the very measurement data called for by prototype measures. The methodology is easily comprehended and executed with minimum training by persons with knowledge of quality management principles. It also calls for an active role by the customer (in whose organization a survey is to be taken)

when developing the survey tool, a practice consistent with the philosophy of Total Quality Management.

Applying the above methodology, the author then develops a questionnaire that incorporates performance measures specific for the Vendor/Contractor activities of a sample organization called *Delta*. The tool permits an exhaustive collection of information for both qualitative and quantitative measures. It is quickly understood by respondents and, consistent with the TQM philosophy, is developed with employee participation from organization *Delta* itself.

In order for VCR measurement data to be of operational value it must ultimately be stored, retrieved, and analyzed. Indeed, measurement data collected for other modules of a QMS (in addition to the VCR module) would similarly need to be collected, stored, retrieved, and analyzed before it could be useful in QMS development. The author envisions that a significant collection of such measurement data might be put to use in many ways. The following hypothetical example is offered.

Many different vendors circulate a questionnaire to employees of their customer organizations; the same the process is completed more than once a year. Because all customers are within the same industry and share similar work environments, the same questionnaire is circulated.

Consultant "A" receives all completed questionnaires thereby collecting exhaustive VCR measurement data for numerous vendor/customer relationships. Using a system designed to store, retrieve, and analyze this information, the consultant then provides analytical feedback to each of the vendors and customers regarding the performance of their respective vendor/contractor (QMS) activities. With the totality of information available, it also becomes possible for the consultant to determine (VCR) performance benchmarks and to use all data in other ways for still further feedback to vendors and customers about their performance.

To meet the needs of the hypothetical consultant, the considerable amounts of measurement information would need to be organized and stored in an automated system. One known way to do this is through the use of a database. To design a database, one must first organized one's data in some logical manner. In Chapter 6 of this project, the author focuses attention on creating a prototype data model for organizing the data collected with the questionnaire developed in this Chapter. Specifically, the applicability and utility of the E/R model are evaluated in creating a logical design for VCR measurement data. If suitable, the same E/R modeling techniques might one day be employed to create models for the measurement data of other modules of the QMS.

# CHAPTER 6: ENTITY-RELATIONSHIP MODELING OF MEASUREMENT DATA FOR THE VENDOR/CONTRACTOR RELATIONS MODULE OF A QMS

## 6.1 INTRODUCTION

Measurement data collected via a questionnaire like the questionnaire developed in Chapter 5 (for Vendor/Contractor Relations activities) must ultimately be organized and analyzed in order to understand its implications. An automated database is most helpful for this work. Databases offer reliable, convenient ways to store, retrieve, and update large quantities of data - in this case, quality-related measurement data. They also permit the manipulation of data for maximum analytical inference.

The modern database is usually based on one of four types of data models: hierarchical, network, relational, and object-oriented. In general, the models reflect different ways of organizing and storing data. In a database based on the hierarchical model, for example, data elements are stored using nested data structures. In a network database, the hierarchical model is generalized and data are organized in a network of nodes and links. In a relational database, all data are stored in a tabular format.

Organizing data into one of the above models is a

necessary first step in developing a database. All potential data elements must be identified and defined and their inter-relationships established. To facilitate these steps, a number of software design aids are available. One aid, the "Entity-Relationship Model" ("E/R" Model), is perhaps the most important and widely used. The E/R model provides a high-level, "logical" view of one's data and is closest to the relational model.

Essentially, the E/R model is an information model. Developed in 1976 by Peter Chen, it is based on three major building blocks - "entities," "relationships," and "attributes." If one likens an E/R model or diagram to a graphical language that expresses statements about a particular business or work environment, "entities" in an E/R model function as nouns, "attributes" as adjectives, and "relationships" as verbs. To model information about an environment, the three need to be organized according to specific E/R rules or semantics.

## 6.2 OBJECTIVES

The first objective of this Chapter is to identify the requirements of a database able to store, retrieve, and analyze measurement data collected by the questionnaire for the Vendor/Contractor Relations (VCR) module of a QMS. (VCR measurement data were collected via the prototype

questionnaire developed in the previous Chapter.) The second objective is to acertain the reliability of the E/R modeling approach in defining a logical model that effectively meets the initial requirements. In this Chapter, the author builds a prototype data model using E/R modeling semantics and constructs and then depicts this model in diagram form. He subsequently traces back to the original data requirements and evaluates if they have been met. Development of the logical model is a first step in designing a Vendor/Contractor Relations Measurement Database.

## 6.3 DEFINITIONS OF THE E/R MODEL

The E/R model has been defined at two levels - simple and complex. The simple definition is used by most computer-aided software engineering tools. With it, the primary classes of information - entities, attributes, and relationships - are described simply in diagram form. Special constructs are included in the simple form such as the concepts of "existence dependency" and "identification dependency." Other special concepts and constructs are added to avoid cluttering an E/R diagram [Teorey, 1990, p.2].

The complex definition of the E/R model on the other hand includes concepts that go beyond the simple model.

Included, for example, are concepts from the semantic models of artificial intelligence. With such enhanced concepts, a database designer can capture additional semantics about his/her data and its interrelationships without having to resort to narrative explanations. The complex definition is also useful to the database applications programmer because a number of requirements defined in the complex E/R model relate directly to the code. The additional details built into the complex level of an E/R model, however, can detract from end-user understanding. This is especially true for large E/R diagrams. For these reasons, the simple level is a preferred communication tool for database design and verification [Teorey (1990), p.2] and, consequently, is used in this research.

## 6.4 REASONS FOR CHOOSING THE E/R MODEL

The E/R modeling technique is a top-down approach that uses the concept of abstraction to simplify the task of analysis. The technique abstracts "entities," which are a group of like objects, and studies the interrelationship between them. This reduces the total number of interrelationships needed to be studied [Teorey (1990), p.34]. In the case of Vendor/Contractor Relations measurement data, numerous vendors may exist, each of which has unique relationships with different customers. Given

the concept of abstraction afforded by the E/R model, it is simpler to abstract the entities VENDOR and CUSTOMER, for example, and to study their interrelationships as a group, than to study the specific data requirements between each and every vendor and each and every customer.

Also, in E/R modeling, "attributes" that describe "entities" are grouped together with each entity.[5] Since attributes normally have relationships with other attributes of the same entity or with attributes of entities that are directly related to their (own), the grouping of like objects into entities greatly reduces the task of analyzing inter-attribute relationships as well [Teorey (1990), p.34]. Again, in the case of VCR measurement data, most data elements are "attributes." Use of the E/R modeling approach therefore simplifies the task of analyzing these many individual attribute interrelationships.

Additionally, this Chapter is limited to the development of a logical model for (the measurement data of) a single module of a QMS, specifically, the Vendor/Contractor Relations module. If successful, still other modules of a QMS may be considered as candidates for abstraction. Eventually, a logical representation of the measurement data for an entire QMS might be achieved. Such

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[5] For easy reference throughout this Chapter, all names of entities are capitalized.

a representation would necessarily involve a large magnitude of data. But again, because of the use of abstraction, E/R modeling would ease the task.

Other reasons for choosing the E/R model for this project are its simplicity and strength as a communication tool. E/R modeling semantics force a database designer to concentrate on the details of data relationships. This helps to capture detail more accurately. In the case of the prototype model, E/R semantics force a designer to ask, among other questions: What is the nature of the relationship between VENDORS and QUESTIONNAIRES? One-to-one? One-to-many? Many-to-many?, etc. Analysis shows that a vendor may circulate many questionnaires but that a questionnaire may only be circulated by one particular vendor. The relationship between the two is therefore defined as one-to-many and can be so represented in a logical model. A final graphic presentation makes all such details easily understood by both designer and end-user.

Finally, if a relational database is found best suited for QMS measurement data, a prototype E/R model is readily translatable into a structured query language (SQL) constructs. This facilitates transfer of the conceptual data model to the next design level, from which a database programmer may ultimately implement a database.

## 6.5 STEPS IN THE DEVELOPMENT OF A DATABASE

As outlined by Teorey (1990), the life cycle of a database takes the following course:

1. Requirements Analysis
2. Logical Design
   a) ER modeling
   b) View Integration
   c) Transformation of ER model to SQL relations
   d) Normalization
3. Usage Refinement
4. Data Distribution
5. Local Schema and Physical Design
6. Database Implementation, Monitoring, and Modification [Teorey (1990), p.3-6].

Steps (1) and (2a) are completed in this Chapter for the Vendor/Contractor Relations measurement data obtained via the questionnaire developed in Chapter 4. The remaining steps lie beyond the scope of this research.

## 6.6 REQUIREMENTS ANALYSIS

### 6.6.1 Delineation of Primitive Objects and Their Interrelationships

A VCR Measurement Database is to be created for

purposes of storing, retrieving, and manipulating measurement data collected from questionnaires that are circulated by numerous vendors (of products and services) to their respective customers.[6] The database will be maintained by an independent consultant to whom questionnaires are ultimately returned. The consultant's task is to input all data, analyze it to meet various objectives, and provide feedback to vendors and customers alike. The consultant is skilled in database operation but unskilled in database design. Since E/R modeling is a useful communication tool, graphic in nature and not too difficult to learn, the consultant is less reluctant to participate in the design process.

First, vendors circulating questionnaires can issue more than one questionnaire to any customer organization. Vendors must be identified by a unique vendor i.d. number assigned by the consultant. The vendor i.d. is not only a unique number for the vendor but also associates him/her to the organization they belong. Vendor name, address, telephone, and fax number must also be associated with each questionnaire. The reasons for these requirements are as follows:

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[6] All customers are assumed to received the same questionnaires.

a. The consultant user will need to contact vendors for such reasons as information verification, analytic feedback, clarification, etc.
b. Responses to every questionnaire must be traceable to the vendor that issued the questionnaire.
c. Information specific to any one vendor must be fully obtainable.

A single customer in an organization can respond to more than one questionnaire coming from the same vendor or different vendors. Customers who respond to questionnaires must be uniquely identified with an i.d. number, again determined by the consultant. This i.d. number is unique to the individual awnsering the questionnaire and associates them with their particular organization. Because individuals within a customer organization who complete a questionnaire are identified on a questionnaire by their name, title, contact phone and fax numbers, this information needs to be reflected in the database. Additional reasons for these user requirements are listed below:

a. The consultant user wishes to trace all questionnaire responses (i.e., measurement data) to the customer organizations from whence they came.
b. The user needs to trace particular responses to individuals within a given customer organization.
c. The user wishes to trace responses to specific levels

of management (within a customer organization) as might be reflected in respondent job titles.

d. Phone and fax numbers facilitate direct, rapid contact with respondents for data verification and other needs. They also further distinguish individual respondents from each other.

Thirdly, three elements need to be recognized in the database as concerns the questionnaire itself. Each questionnaire must be uniquely identified by a serial number. A serial number should be a unique alpha-numeric identification that designates the "type" of questionnaire at the end of the number.[7] Each questionnaire must also be traceable to the vendor that issued it, the customer receiving and responding to it, and the customer's organization, which is implicit in the customer's i.d. number. A database must recognize the date that each questionnaire is completed. All of these features are needed by the user for the following reasons:

a. The consultant user wishes to associate all responses in a particular questionnaire (i.e., its measurement

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[7] The "type" of a questionnaire refers to the department or area of business within a customer's organization from which measurement is being collected. For example, a questionnaire completed by an individual in the "Design Assurance" department would have a two digit code "DA" at the end of his/her questionnaire serial number.

data) with the unique vendor-customer pair described by the responses.

b. The user needs to track changes in questionnaire responses over time.

In every questionnaire (designated by a serial no.) there are many responses corresponding to the many questions contained in it. All responses need to be traceable to the individual who completed the questionnaire. Also, the database needs to reflect that each question is repeated in many questionnaires and thus will have many responses in those different questionnaires.

Within each questionnaire, individual question items are uniquely identified by a question i.d. number. This information must therefore be provided for within a database. The database must also identify: the nature of every question as either qualitative or quantitative; the individual text of each question; and the various units of measures associated with particular quantitative question items, e.g., units such as percentage, minutes, etc. Though not yet included in the prototype questionnaire, the author foresees future value in assigning relative weight to qualitative responses. Since this is known at this time, the user would like a VCR Measurement Database to be able to assign each qualitative question its designated relative weight. All of the above requirements are needed for the

following reasons:

a. The consultant user wishes to trace all responses to the question items that prompted them.

b. For purposes of identification and analysis, quantitative and qualitative scores need to be distinguished as separate question items.

Responses to question items must finally be stored in a VCR measurement database. The database must be capable of distinguishing between qualitative and quantitative answers. It must further be possible to trace responses to their associated questions. Since any given vendor may send the same questionnaire type to a number of different customers, there will be numerous responses to the same question (in a questionnaire) depending on how many questionnaires are actually completed. This makes it imperative that all responses stored in the database be traceable to the serial number of the questionnaire from which they come.

### 6.6.2 Processing Requirements

Listed below are sample queries that the consultant user may wish to pursue with a VCR Measurement Database. The queries are by no means exhaustive.[8]

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[8] In addition, each of the following queries may be asked of a particular "type" of questionnaire (as this term has already been explained).

a. How does a given individual in a customer organization rate his/her vendor/contractor relations?, i.e., What is the total score for a particular questionnaire?[9]

b. What is the trend over time for the performance scores that one individual has given for the same vendor?

c. What are the average scores given to a vendor by different respondents in a particular customer organization? What are the scores for an entire organization? (An analagous query may also be formulated for particular questions in a questionnaire.)

d. What are the low, average, and high scores received by a vendor on the set of questionnaires sent to its different customers?

e. What are the low, average, and high scores received over time by a vendor on the set of questionnaires sent to its different customers?

f. What are the average, high, and low scores for each question on a questionnaire for all vendors of a particular customer?

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[9] "Score" refers to the answer given on a qualitative question.

g. What are the average, high, and low scores over time for each question on a questionnaire for all vendors of a particular customer?

h. What scores are received by a vendor for questionnaires responded to by upper management vs. those responded to by middle or lower management?

i. What are the responses for any given measure? for a particular set of measures?

j. What are the ranges of survey scores - highest and lowest - for a given measure or set of measures?

k. What are the average scores for a given measure or particular set of measures?

l. What are the survey scores for quantitative measures alone? for qualitative measures only?

m. What changes are reported for a particular measure (or set of measures) over time for a given vendor or customer?

n. How do scores of one vendor or customer on a given measure (or set of measures) compare with the scores of other vendors or customers?

o. What scores on a given measure (or set of measures) characterize a particular group of vendors or customers at a particular time? What are the "industry norms?," i.e., ranges and

average scores for certain vendor/contractor quality-related behaviors?

The above sample queries will ultimately need to be handled by a Vendor/Contractor Relations Measurement Database. A prototype logical (data) model should be structured to accommodate these information requirements as fully as possible.

6.6.3 Processing Requirements Updates

a. Occasionally the addresses, phone numbers, fax numbers, and even the names of vendors and customers themselves will change. The user will wish to keep this information current, updating the information on a quarterly basis.
b. New customers and vendors must be added to the database.
c. Questionnaires may be modified from time to time to better reflect changing business climates, vendor/contractor activities, the focus of system measurement, changes in the quality management criteria, etc. The existence of a revised questionnaire will need to be uniquely identifiable.

## 6.7 BUILDING OF A PROTOTYPE LOGICAL MODEL FOR VENDOR/CONTRACTOR MEASUREMENT DATA

Keeping in mind the requirements and sample queries specified by the database user, and considering all data elements, a logical (data) model was developed in the following manner.

### 6.7.1 Classification of Entities and Attributes

Entities that naturally came to mind were: VENDOR/CONTRACTOR, CUSTOMER, and QUESTIONNAIRE. These elements represented the obvious, major "objects" about which (and through which) one would collect vendor/contractor-specific quality information. Since measurement data for the module primarily concerns the relationship between VENDORS and CUSTOMERS, much information existed to be modeled for these two elements.

Descriptors such as address, phone number, and fax number were identified as some of the attributes of these two entities. An attribute that would uniquely identify the separate instances of the VENDOR entity was "Vendor i.d. number." "Customer i.d. number" would similarly identify separate, unique instances of the entity CUSTOMER. These two were therefore chosen as the primary keys for the two entities.

A third major entity was considered next -

QUESTIONNAIRE - the tool by which one might learn of an organization's relations with its vendors and contractors. The questions contained in a vendor's (or contractor's) questionnaire, as well as the many question responses, were initially modeled as attributes of the entity QUESTIONNAIRE. Upon closer examination, however, it was clear that both elements - question and response - should themselves be viewed as entities since descriptive elements existed to identify each.

The attributes "question text," "question type," and "question i.d," for example, were found to characterize both elements. The primary key "question i.d." was determined to be the unique identifier for each instance of the entity QUESTION. Upon analysis, the entity RESPONSE was found to have the unique non-key attributes "quantitative response" (or "quant. response") and "qualitative response" (or "qual. response"). Quantitative responses would clearly assume any numeric value. Qualitative responses, however, would take values between 1 and 5 as these numbers are defined by the Likert Scale. Since the questionnaire gives a respondent no choice other than 1 through 5, there is no need to further define this particular range of values. Should a range of values need to be defined in the future for any reason, it could be done using an advanced E/R modeling construct such as "domain." Advanced constructs have not been pursued in

this research.

### 6.7.2 Identification of Generalization Hierarchies

In course of the modeling effort, it was eventually clear that for the two basic types of questions - QUALITATIVE and QUANTITATIVE - a supertype could be defined. The supertype defined was QUESTION. The QUALITATIVE and QUANTITATIVE questions were therefore modeled as subtypes of the generalization entity QUESTION. These two types had three attributes in common: "question type," "question text," and "question i.d." These attributes migrated to the supertype entity (QUESTION). "Question i.d.," which was the primary key of the supertype entity, also migrated to the subtype entities. Non-key attributes specific to each subtype, such as "unit" (of measure) for the QUANTITATIVE QUESTION subtype, and "weight" (or relative weight) for the QUALITATIVE QUESTION subtype, were assigned to their respective entity.

### 6.7.3 Definition of Relationships

A number of relationships were defined between entities when building the prototype model. In considering the relationship between VENDOR and CUSTOMER, it was apparent that many VENDORS might easily be associated with many CUSTOMERS, and vice versa. Both groups, however, were also

associated with a third entity, QUESTIONNAIRE: 1) VENDOR circulates QUESTIONNAIRE, and 2) CUSTOMER fills out QUESTIONNAIRE.

Each parent entity, VENDOR and CUSTOMER, thus have identifying relationships with a child entity, QUESTIONNAIRE. The connectivity of these two sets of relationships is one-to-many. The cardinality of each parent-child relationship is one-to-one-or-more. This means that in each relationship, one instance of the parent entity (VENDOR or CUSTOMER) is related to at least one or more instances of the child entity QUESTIONNAIRE.

In analyzing associations between all entities, it was apparent that the entity QUESTIONNAIRE also had relationships of its own. The connectivity of the relationship between (the entities) QUESTIONNAIRE and QUESTION was initially seen to be many-to-many, i.e., for one questionnaire there could be many questions, and any single question might appear in a number of different questionnaires that were circulated.

It was clear, however, that while the responses contained in a questionnaire could in fact be many, each response would be unique for a given questionnaire. A one-to-many relationship could therefore be defined between these entities (QUESTIONNAIRE and RESPONSE) since the serial number identifies a unique questionnaire for which one would

have many responses unique to that questionnaire. Similarly, a question could have many responses in different questionnaires. Hence, between the entities QUESTION and RESPONSE, a second one-to-many relationship also was defined.

## 6.8 PROTOTYPE LOGICAL E/R MODEL

A "logical level" view of the prototype model is depicted in Figure 9. This view provides the broadest overview of the model's many components. It illustrates all entities (independent and weak), their interrelationships, the connectivity and cardinality of all relationships, and key and non-key attributes.

## 6.9 CONCLUSION

As previously mentioned, the third and final objective of this research project involved data modeling. A prototype logical model was created to demonstrate the applicability and utility of the E/R model in meeting the data requirements for a model of a Vendor/Contractor Relations Measurement Database. The model offers a simple and graphic tool for abstracting this measurement data.

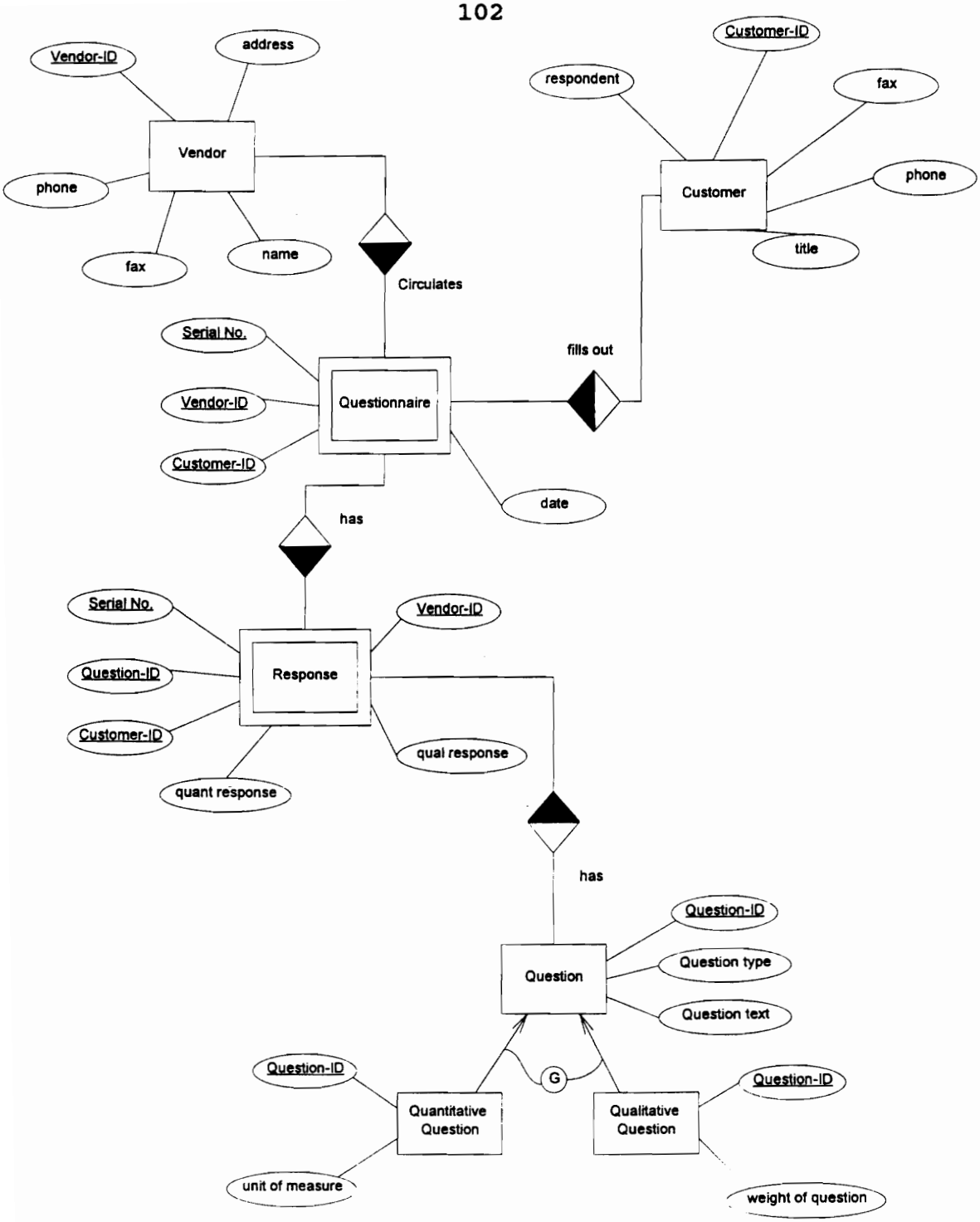


Figure 9. E/R Logical Model

As depicted in Figure 9, entities VENDOR and CUSTOMER are identified by i.d. numbers and specific attributes that permit them to be distinguished uniquely. Every questionnaire is uniquely distinguished through its own serial number and the vendor i.d.-customer i.d. combination specific for it. Responses to questions - distingished as either qualitative or quantitative - are traced still further to given vendor-customer pairs, specific questionnaires, and to particular questions themselves. The model stores every question and question text through a unique i.d. number corresponding to its number in a questionnaire. Units of measure associated with quantitative responses are captured; the relative weight of qualitative questions is also reflected in the prototype model.

Given the current model, all of the queries to be asked of a database as set forth in this Chapter are answerable with the exception of query "h." How a given individual in a customer organization rates his/her vendor/contractor relations, for example, query "a", is determined by the total score for a particular questionnaire, which may be calculated and traced to the person who completed it (via questionnaire serial no., vendor i.d., and customer i.d.). The trend in the performance of a vendor over time (as assessed by an individual customer) is captured in the

changes in the individual's questionnaire scores over time for the vendor; to answer such a query, one would first identify the vendor-customer pair in question, locate respondent questionnaires using the appropriate vendor i.d-customer i.d. combination, review the questionnaire scores, and sort all questionnaires by date to observe changes in scores over time, if any.

How does a customer organization as a "whole" rate or review a particular vendor? The answer to this, query "c", is reflected in the average (questionnaire) scores of all customer respondents for a given vendor. Since the first three characters of a customer i.d. number denote a customer's organizational affiliation, all respondents from the same organization (regarding a certain vendor) could be identified, their questionnaire scores reviewed, and a total "picture" gleaned of their collective assessment of a vendor's performance.

Since the prototype model also tracks individual responses for each measure, one can use question i.d. no. to look at the range of scores for a particular measure or the changes in particular scores over time as they are given, say, by a certain group of customers (defined by their customer i.d. no.) or received by a particular group of vendors (defined by their vendor i.d. no.). In short, a number of unique identifiers link the various entities in

this prototype model and allow one to answer all but one of the sample queries posed.

Query "h" may effectively be answered only if an additional attribute ("management level") is added to the entity CUSTOMER. Data for this attribute is perhaps best added by the consultant user (rather than a respondent him/herself) based on the consultant's review of the various respondent's titles returned on questionnaires.

The finished prototype model lays an important foundation for a future database that could effectively store and manipulate measurement data gathered via the questionnaire developed in Chapter 5 for the VCR measures - measures themselves developed earlier in Chapter 4. Thus, in this Chapter, a significant step is taken to operationalize performance measures for a single module of a QMS. The entire process - creation of performance measures for a QMS module, data collection for the measures, and an initial conversion of such data to useable information for the purpose of feedback and QMS module development - is a unique contribution of this research.

# CHAPTER 6: QUALITY MANAGEMENT SYSTEM MEASUREMENT: PRESENT AND FUTURE

## 7.1 OBSERVATIONS OF RESEARCH

The research presented in this document meets the objectives set forth at its outset. Like all research, it is never complete. Hindsight leads to discovery of areas that might have been handled differently if research were begun anew, and one's work always raises many ideas for further investigation. In concluding this thesis, this final Chapter addresses the accomplishments, strengths, and weaknesses of the present research. It also introduces new ideas in the field of QMS development and measurement raised in the course of this study.

The first objective of this research was to develop a methodology for identifying generic measures for the performance and evolution of a QMS using the operational definition of a QMS earlier identified by Triantis, et. al (1991b). The author achieves this goal. The methodology put forth offers an uncomplicated approach to QMS measurement that may be satisfactorily applied to all work environments. It addresses the comprehensive QMS activities and remains flexible enough to accommodate QMS activities not already identified or which may be identified in past or

future professional literature.

A weakness of the methodology is its dependence on the user for high-quality results. The ultimate power and utility of any measures developed with the methodology will be determined (in large part) by the knowledge, experience, commitment, diligence, thoroughness, and insight of those (stakeholders) who participate in the process. However simple and straightforward, the methodology is not by itself a formula for success.

To illustrate the methodology, the author creates a substantial number of unique measures able to capture changes in QMS activity. The measures - developed for 10 of a QMS's 37 modules - are user-friendly and "generic," i.e., applicable to any work environment in the business or government sectors. All measures are presented with complete definitions and grouped according to the modules to which they apply. They reflect both qualitative and quantitative aspects of QMS measurement, vital components for any complete evaluation of a QMS. Both the measures and the methodology that gave rise to them may be viewed as the first contribution of this thesis.

A limitation of the prototype measures is the need to further operationalize them before use in a particular environment. Standing as they do, the generic measures lack specificity to adequately and accurately evaluate the

quality-related processes, services, and products of a given work place. They must first be tailored with well-conceived examples or "instances" before they can best fit the system measurement needs of an organization. Though developed as exhaustively as possible, room remains for still other measures that may add to the comprehensiveness of the list.

A second objective of this research was to operationalize measures of quality within an organization. The author therefore puts forth a second methodology for developing a survey tool - specifically a questionnaire - to collect the very measurement data called for by prototype measures. This second methodology is again simple and straightforward. More importantly, it calls for an active role by the customer (in whose organization a survey is to be taken) when developing the tool, a practice consistent with the philosophy of Total Quality Management. A questionnaire developed using the approach suggested by the author will benefit from: 1) the knowledge and expertise of experts/consultants who have participated in its development, as well as 2) the intimate experiences of the stakeholders of a business. Such a cooperative effort increases the sense of ownership of a questionnaire by all surveyed. It also promotes greater understanding of QMS functioning within an organization.

To illustrate the second methodology, the author goes

on to develop a prototype questionnaire. This questionnaire furthers the work accomplished in the first objective. The questionnaire collects data for measures specifically developed for the vendor/contractor relations module (of a QMS). Before the measures could be included in the questionnaire, all were tailored to the needs of a sample organization called *Delta*. With the questionnaire, both qualitative and quantitative data are collectable. The tool permits an exhaustive collection of information about each measure. It is quickly understood by respondents, and was developed with employee participation from organization *Delta*. Both the questionnaire and the measures contained within it build upon the author's initial work and serve to further operationalize the use of measures for a QMS.

Four areas of investigation regarding the prototype questionnaire are left unaddressed in this thesis. The first is a need to evaluate the reliability and validity of all items in the questionnaire. A second need is for qualitative responses to be weighted (in their relative importance) so that scoring can become most meaningful. The third item of importance is the application of a sound statistical evaluation technique for evaluating the final results of the questionnaire. (This, in fact, might be automated by incorporating the function into a (final) DBMS that could store such data.) Last, a methodology is needed

for relating quantitative and qualitative scores so that scoring might be fully integrated. Certain ranges of quantitative scores, for example, could be equated to values on a scale of 1-5, the same response scale utilized with qualitative responses. Such "equating" or "relating" of scores would optimize the capacity of the questionnaire to yield maximum information about an organization's objective and subjective quality-related activities.

To have utility, measurement data must ultimately be stored, retrieved, and analyzed. To complete the work of this thesis, and as a third and final objective, the author employs E/R modeling techniques to create a logical model for organizing measurement data that is collected via the prototype questionnaire for a VCR module. The model offers a simple, complete, and graphic tool for organizing this data and appears to meet the requirements analysis set forth. It also represents a key step in designing a database for VCR measurement data.

The modeling results achieved in this project could be furthered in a number of ways. First, the author has applied only basic E/R constructs. More advanced constructs could be employed to communicate additional information and to make the model more efficient. The construct "domain," for example, could be used to define a five-point scale in the database to correspond with the five-point agree-to-

disagree continuum associated with qualitative responses allowed in a questionnaire. Equally valuable would be the planning of additional queries and update processing requirements. The remaining steps in the life cycle of a database also, obviously, stand to be addressed as the present logical model is but a prototype.

In sum, the unique contribution of this research is an entire process: creation of measures for the performance and evolution of a QMS module, collection of data for these measures, and an initial organization of data into a model for ultimate development of a database.

## 7.2 THE FUTURE OF QUALITY MANAGEMENT SYSTEM MEASUREMENT

Strategic Quality Management is here to stay. Its success in facilitating excellence in product/service quality, improved bottom lines, and increased motivation is real. In time, its implementation will expand and grow increasingly sophisticated requiring even more sophisticated tools in its control and development. Automated survey tools integrated with databases are sure to become popular. Highly refined, precise, and complete measures will necessarily form a critical base.

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# APPENDIX A

## GLOSSARY OF TERMS

## GLOSSARY OF TERMS

QMS-, measurement-, questionnaire-, and E/R modeling-related terms used in this research project are defined here to promote the reader's fullest understanding. For the most part, terms are listed in alphabetical order. Terms associated with one another are presented as a group and are not, therefore, necessarily in alphabetical order.

1. Attribute

An attribute is a unit of measurement or an identifiable characteristic of a variable [Sink (1985), p.25]. Size, color, age, personality, response time, quality, quantity, or weight are examples of different attributes. A variable may be defined and described by one or more attributes.

2. Attribute (As Defined In E/R Modeling)

Attributes describe or characterize entities and relationships [Teorey (1990)]. (See item #6 for a definition of "entity" and item #22 for a definition of "relationship.") Attributes are one of three major building blocks in E/R modeling. In the E/R diagram depicted in Figure 9, the attributes of an entity are placed inside oval shapes and connected to the entity (to which they apply) via

straight lines. As shown, attributes of the entity VENDOR include the properties "(vendor) i.d.," "(vendor) name," "phone," "fax," and "address."

2.1 Key and Non-Key Attributes

The set of attributes that identifies an entity is called the entity's key. A key attribute (also known as a primary key or identifier) is an attribute which, by itself or in combination with other key attributes, identifies a unique occurrence of an entity [Teorey (1990)].

In the case of the prototype logical model developed for this research project, the key attribute of the entity VENDOR is "vendor I.D." In Figure 9, key attributes are underlined. Non-key attributes of this same entity are "(vendor) name," "phone," "fax" and "address;" they are not underlined. In relational databases, the different attributes of entities are stored in different columns of a relational system.

2.2 Foreign Key Attribute

Foreign key attributes are defined as primary key attributes of a parent entity contributed to a child entity across a relationship. The contributed keys are said to "migrate" from parent to child [Bruce (1989-1991), p.21]. (Item 6.4 discusses "parent" and "child" entities.)

In the prototype model for Vendor/Contractor measurement data, primary keys from two parent entities

(VENDOR and CUSTOMER) have been contributed to the child entity QUESTIONNAIRE. (See Figure 9) "Vendor ID" and Customer ID," the primary keys, have migrated from parent to child.

3. Continuum

A continuum refers to a series or spectrum; when used with a particular scale, it reflects a range of possible responses [Hayes (1992)].

4. Customer

Any party affected by an organization's product or service is a customer. Customers may be individuals, groups or institutions. They may be both external or internal to an organization [Juran (1991), p.2.2].

4.1 Customer Satisfaction

"Customer satisfaction" and "perception of quality" are labels used to summarize a certain set of customers' observable actions related to a product or service. Customers may smile when they talk of a product or service or they may say good things about it. Both actions are manifestations or indicators of "customer satisfaction" [Hayes (1992)].

Other observable manifestations of satisfaction are the responses given by customers on a customer satisfaction

questionnaire. If persons indicate good things about a product on a questionnaire and demonstrate other indicators of positive behaviour, one can conclude that they are satisfied with a product [Hayes (1992), p.29-30].

4.2 External Customer

External customers are parties affected by a product or service who/that are not members of the organization producing the product or service. External customers may be as diverse as individuals, groups or institutions that purchase a product or service, government agencies that regulate a product or service, or the public that evaluates a product or service [Juran (1991), p.2.2].

4.3 Internal Customer

Within any company or organization there are numerous situations in which departments and persons supply products to each other. The recipients of these products or services are called "internal customers" [Juran (1991), p.2.2].

## 5. Entity-Relationship Modeling

Entity-relationship (E/R) modeling is a modeling approach that uses the concept of abstraction to organize and analyze data elements into a logical model that can be used for a database design. "Entities," "attributes" and "relationships" are the primary building blocks of an E/R model.

## 6. Entity

In E/R modeling, entities are the principle data objects about which information may be collected from an organization's (or user's) environment. They may be thought of as a set or collection of like individual objects - usually persons, places, things, or events of informational interest [Teorey (1990), p.11-12]. Figure 9 depicts the entities identified in the prototype logical model for Vendor/Contractor measurement data. These include VENDOR, CUSTOMER, QUESTIONNAIRE, RESPONSE, and QUESTION. Each entity is denoted by a rectangular box with its name written within the box.

### 6.1. (Entity) Instance or Occurrence

A singular occurrence of an entity is called an instance or entity occurrence. Each instance must have an identity distinct from all other instances. In the structure of a relational database, an entity corresponds to a table in the database whose rows consist of possible instances of the entities [Bruce (1989-1991), p.11-12].

### 6.2 Weak Entity

In E/R modeling, entities are commonly designated as either weak or independent. Weak entities depend on an associated entity (or entities) for their existence and identification within a database. They derive their identities from the identifying attributes of one or more

"parent" entities. In the prototype model for this research, QUESTIONNAIRE is a weak entity. (See Figure 9) Its existence derives from its relationship with VENDORS (who circulate questionnaires) and CUSTOMERS (who complete questionnaires). Weak entities are represented in the prototype model by double-lined rectangles. (See Figure 9)

6.3 Independent Entity

Independent entities do not depend on any other entity in a model for their existence or identification. VENDOR and CUSTOMER are independent entities in the prototype logical model. They are denoted in Figure 9 by a rectangular box.

6.4 Parent and Child Entities

A parent entity is the entity on the "one" end of a one-to-many relationship. The entity on the "many" end is referred to as the child entity. (See item #22.2 for a discussion of connectivity in E/R modeling and the meaning of "one-to-many.")

7. Employee Beliefs

The beliefs of employees about quality include their convictions, certainties or accepted opinions regarding the principles of quality management and the importance of service/product/process quality for their organization [Triantis, et. al. (1991b)].

8. Employee Attitudes

Attitudes of employees about quality (management) reflect their positions, dispositions, manners and acceptance of quality principles; attitudes toward quality are reflected in daily work habits [Triantis, et. al. (1991b)].

9. Employee Values

Employee values (concerning quality) reflect the worth, excellence or usefulness of TQM principles in the eyes of employees [Triantis, et. al. (1991b)].

10. "Enterprise Level" Quality Management Criteria

Enterprise level management criteria concern the strategic functions of a quality management system [Triantis, et. al. (1991b)].

11. Generalization or Inheritance Hierarchy

In E/R modeling, a set of entities that share common characteristics can be grouped into a generalization or inheritance hierarchy. This is also known as a sub-type, or (sub)category hierarchy [Bruce (1989-1991), p.20]. In the prototype model of this thesis, QUANTITATIVE QUESTIONS and QUALITATIVE QUESTIONS are two (entity) subtypes that share common characteristics. The two are encompassed by the

generalization entity QUESTION and denoted by an encircled letter "G".

A non-key attribute specific for QUANTITATIVE QUESTION is "unit" (of measure); this is therefore added only to the subtype entity QUANTITATIVE QUESTION. A non-key attribute specific for QUALITATIVE QUESTION is "weight;" this, similarly, has been added only to the second subtype entity QUALITATIVE QUESTION. (See Figure 9)

### 11.1 Discriminator

Distinguishing between the subtypes in a generalization hierarchy is a discriminator [Bruce (1989-1991)]. In the case of the prototype data model, the attribute "question type" serves as a discriminator for the generalization hierarchy involving QUESTION.

## 12. Measure

Measure refers to the development and/or selection of a scale by which one assigns "signs" or values to an attribute according to some specified "rules." Signs refer to numerals, letters, or symbols. Rules refer to some consistent logical and valid matching process between the attribute and some scale [Sink (1985), p.25].

### 12.1 Hard Measure

Hard measures are quantifiable, objective indicators of

an attribute. The size or weight of a part is a hard measure commonly used within the manufacturing industry. Within a service industry, a hard measure might be the amount of time elapsed between the date a complaint was lodged and the date corrective action was taken, i.e., the "response time" [Hayes (1992)].

12.2 Soft Measure

Soft measures are subjective in nature. They focus on attitudes, perceptions, beliefs and feelings. They are used to capture stakeholders' perceptions, both external and internal, regarding products or services [Hayes (1992)].

13. Item or Instance of Measure

An "item" or "instance" of a measure is a specific statement about or example of the attributes of a product/service/process being evaluated [Hayes (1992)]. A measure of the quality of a supplier's service, for example, might be the availability of the supplier to a customer; an instance of this measure could be a statement such as: "The supplier was always available to schedule me as I needed."

13.1 Satisfaction Item

A satisfaction item is an instance that describes a positive or negative aspect of a service, product or process being measured. "The merchant gave me an appointment at a convenient time," is an example of a satisfaction item that

might be used in a questionnaire to assess a customer's positive feeling concerning his/her service [Hayes (1992)].

13.2 Neutral Item

A neutral item is an instance that describes an aspect of a service, product, or process without positive or negative connotation. "The convenience of my appointment with the merchant," is a neutral instance concerning a customer's interaction with a merchant [Hayes (1992)].

14. Organization

Any purposeful system or social group whose parts perform different functions that have a division of labor can be called an organization [Blanchard (1981), p.15].

15. "Process Level" Quality Management Criteria

"Process level" criteria concern the specific operational production and service processes of an organization. They represent a quality management system's activities in its most functional terms [Triantis, et. al. (1991a)].

16. Production/Service Process

A production or service process refers to the transformation of inputs (such as materials, supplies and components) into value-added goods or services through the

performance of a set of activities and the utilization of all available resources of an organization. A complete description of a production or service process includes all inputs that are used, the value-adding and cost activities involved, the specific sequencing of operations, and all intermediate and final products/services produced. A production or service process also includes feedback on the product or service received from users regarding the quality performance of the products or services [Triantis, et. al. (1991b), p.4].

17. Productivity

Productivity can be defined in terms of partial measures, e.g., labor productivity defined by output per employee or output per labor hours. Productivity can also be defined to track output according to the changes in a combination of inputs - typically labor, materials, capital and energy. This is known as "total factor productivity" [Triantis, et. al. (1993)].

18. Quality

Quality is a complex construct. Scholars in many disciplines have explored its operational definitions, each bringing a unique perspective and particular analytical framework and terminology to the discussion. Five themes

that encompass most existing definitions of quality and offer a comprehensive framework for considering this construct were identified by David Garvin. These are presented below:

18.1 Transcendent View of Quality

This view equates quality with "innate excellence" and something timeless and enduring. The view speaks of quality as a simple, unanalyzable property, not precisely definable, and recognizable only through experience. The transcendent view of quality suggests that whatever quality consists of, managers will know it when they see it. Little further practical guidance is offered [Garvin (1988), p.41-42].

18.2 Product-Based View of Quality

According to this view, quality is very precise and measurable: differences in quality reflect the presence or absence of some particular ingredient(s) or attribute(s). Quality is considered an inherent characteristic of goods rather than something ascribed. It is determined objectively. The product-based view of quality fails to accommodate differences in taste or preferences [Garvin (1988), p.42-43].

18.3 User-Based View of Quality

The user-based view is highly subjective: quality lies in the eyes of the beholder. This view maintains that quality is defined by the precise combination of

product/service attributes that provide the greatest satisfaction to a consumer. How one distinguishes product attributes that connote quality from those that simply maximize consumer satisfaction is not addressed. How to aggregate widely varying individual preferences so that they lead to meaningful operational definitions also is not addressed [Garvin (1988), p.43-44].

18.4 Manufacturing-Based View of Quality

Virtually all manufacturing-based definitions identify quality as "conformance to requirements." "Making it right the first time" is the rule. Deviations from established specifications imply reductions in quality. In a service setting, conformance generally translates into accuracy or timeliness [Garvin (1988), p.44-45].

18.5 Value-Based View of Quality

Quality is defined in terms of cost and price in a value-based view of quality. "Affordable excellence" reflects this highly subjective hybrid of excellence and worth [Garvin (1988), p.45-46].

19. Quality Cost

Quality costs are expenditures on manufacturing or service beyond those that would have been incurred had the product been built (or service performed) exactly right the first time. In its most comprehensive form, quality costs

include: a) the cost of forgone opportunities (e.g., sales lost), the cost of responding to customer complaints, and other hidden costs, as well as b) the cost of carrying excess raw material and work in process inventory to ensure that defectives do not stop production line.

Quality costs may be categorized as: a) prevention, e.g., supplier education, on-the-job training, product redesign, and other efforts to prevent defects; b) appraisal costs: expenditures on inspection, testing and other activities that detect defects/mistakes; c) internal failure costs, e.g., expenditures on scrap, rework, and activities to correct defects/problems in-house; d) external failure costs, e.g., expenditures on warranty claims, product liability suits, and other problems that arise after a product has reached the customer [Garvin (1988), p.78-79].

20. Quality Management System Assessment

The assessment of a quality management system is an objective, independent review of an organization's quality management practices and capabilities for the purpose of recognizing excellence and/or identifying opportunities to further strengthen the quality-based elements of operational management [Triantis, et. al. (1991b), p.4].

21. Quality Management System

The organizational structure, responsibility, procedures, processes, and resources for implementing quality management within an organization are known collectively as a quality management system [Juran (1991), Appendix IV].

22. Relationship

Relationships, one of three building blocks in an E/R model, represent "real world" meaningful links or interactions between one or many entities in a user's enterprise. The function that an entity plays with another (in a relationship) defines the relationship between them; this function or "role name" is also the name of the relationship itself.

Conventionally, E/R modelers work to ensure that relationship names act as verbs between (the nouns for) entity names. Although verb phrases do not always precisely describe the full relationship between two entities, they allow a person looking at an E/R model to get an initial sense of how the entities are connected. Convention also dictates that in an E/R diagram, entity and relationship names are "read" left to right or top to bottom when describing relationships. In Figure 9, the relationship between VENDOR and QUESTIONNAIRE is read: VENDOR circulates QUESTIONNAIRE. The relationship between the entities

CUSTOMER and QUESTIONNAIRE is read: CUSTOMER fills out QUESTIONNAIRE.

As shown in Figure 9, relationships are displayed with a diamond-shaped figure that connects two (associated) entities; a verb phrase written near the diamond names the relationship. In general, relationships may be further described in terms of three features: their a) degree, b) connectivity, and c) cardinality.

22.1 Degree

The number of entities associated in a relationship reflects the "degree" of the relationship. Degrees can be unary, binary, ternary, or "n"-ary. A unary relationship involves one entity type; this entity relates only to itself. A binary relationship, the most common that occurs in the natural world, is an association between two entities, e.g., QUESTIONNAIRE has RESPONSE. Some modeling systems use only this type of relationship. A ternary relationship is an association between three entities in such a way that the set of associations cannot not be decomposed into equivalent binary relationships. In the course of data modeling, if a set of associations between three entities is conceived as a ternary relationship and can, in fact, be decomposed into equivalent binary relationships, it should be broken down. This keeps the database as clean and simple as possible [Teorey (1990),

p.15].

22.2 Connectivity

The connectivity of a relationship describes the mapping of associated entity occurrences within a relationship. Connectivity takes on values of one or many [Bruce (1989-1991), p.16-17]. In the relationship illustrated in Figure 9, connectivity between the entities QUESTIONNAIRE and RESPONSE is said to be one-to-many. This means that one and only one instance of the first entity (QUESTIONNAIRE) is related or connected to many instances of the second entity (RESPONSE).

A parent entity is the entity on the "one" end of a one-to-many relationship; the entity on the "many" end is referred to as the child entity. Other possible connectivities are many-to-one, one-to-one, and many-to-many [Bruce (1989-91), p.16-17].

22.3 Cardinality

Cardinality is the actual numerical value associated with the the term "many" in a connectivity relationship. It describes the constraint on the number of entity occurrences that are related through a relationship [Teorey (1990), p.16].

22.4 Identifying/Nonidentifying Relationship

Because the keys of a parent entity form part of the identity of a child entity, the child is dependent on the

parent for its identity. Such a relationship is called an identifying relationship.

Non-identifying relationships also connect a parent entity to a child entity. However, since some or all of the migrated keys in this type of relationship are not part of the primary key of the child, the child is not identified by the parent. No such relationships are defined for the prototype data model in Figure 9.

23. Stage Development

Stage development is the systematic iterative process in which a quality management (system) module matures from a basic stage (level) to a more sophisticated stage (level). It is assumed that a quality management module that has achieved a stage above the base stage has satisfied all the requirements of the stages beneath its current stage during its (quality management) development. The "stage" of a quality management system depends upon the cumulative effect of its different modules, i.e., on their respective "stages" [Triantis, et. al. (1991b)].

Triantis et. al. (1991b) defines three distinct "stages" through which the modules of an organization may transition. These three stages are not the only stages in the life cycle of the quality management system, however. When an organization reaches the third stage of development,

one can define three additional stages through which the QMS may develop. This is consistent with the philosophy of Total Quality Management (TQM), which explicitly stresses continuous development at any given time [Triantis, et. al. (1991b)].

24. Stakeholder

The stakeholders of an organization include its employees, managers, internal and external customers, shareholders, suppliers, vendors, and any additional parties who have interaction with the organization, e.g., banks, regulatory agencies, etc. [Triantis, et. al. (1991b)]

25. System

A system is an assemblage or combination of elements or parts forming a complex or unitary whole such as a river system or transportation system; any assemblage or set of correlated members such as a system of currency; an ordered and comprehensive assemblage of facts, principles, or doctrines in a particular field of knowledge or thought such as a system of philosophy; a coordinated body of methods or a complex scheme or plan of procedures, such as a system of organization and management; any regular or special method or plan of procedure, such as a system of marking, numbering, or measuring.

Not every set of items, facts, methods, or procedures is a system. A system must have 1) unity, 2) functional relationships and 3) useful purpose. A random set of items lying on a table, for example, would constitute a set with definite relationships between the items, but they would not qualify as a system because they lack the three essential criteria of a system - unity, functional relationships and a useful purpose [Blanchard (1981), p.2-3].

26. (System) Input

System inputs are primarily the resources required by activities to produce a desired output; they represent any and all information, materials, expertise, manpower, and resources [Triantis, et. al. (1991b)].

27. (System) Activity

Activities are equivalent to "processes" in a system. Activities convert system inputs into outputs that have utility [Triantis, et. al. (1991b)].

28. (System) Output

System outputs are the results obtained through a direct transformation of inputs by the activities in a system [Triantis, et. al. (1991b)].

29. (System) Feedback

Feedback is the process by which the performance of a system is evaluated and changes recommended so as to achieve desired goals and objectives [Triantis, et. al. (1991b)].

30. Total Quality Management (TQM) System Module

A system module is a collection of TQM criteria that share common quality-related objectives and characteristics. Each module represents an important piece of an organization's TQM behaviour and can be analyzed as an input/output system [Triantis, et. al. (1991b)].

# APPENDIX B

## PROTOTYPE PERFORMANCE MEASURES FOR SELECTED MODULES OF A QUALITY MANAGEMENT SYSTEM

NOTE: The measures that follow have been excerpted from the complete list of measures for (all) 37 modules of a QMS originally published in "Document E" by Triantis, et. al., 1993. The selected measures were developed by the author of this thesis in the course of his graduate research. The numbering scheme is the original numbering scheme established for the entire set of measures, i.e., for all 37 modules of a QMS, and should not be confused with any other numbering scheme within this document.

## 2.6 MEASUREMENT/DOCUMENTATION/MANAGEMENT & ANALYSIS OF QUALITY DATA & INFORMATION

### 2.6.1 Quality Measurement

Definition: Transformation of quality data and information into meaningful indicators that can give employees and managers the ability to control and improve the organization's processes and quality management system.

#### 2.6.1.1 Overview of the Measures and the Associated Descriptive Information for Measurement[1]

Listing of Measures

| | Cross Reference Section - Measure # |
|---|---|
| 1) Quality costs related to integrating quality into management activities | |
| 2) Measures of employee involvement in the improvement of measurement procedures | 2.7.1.1 - #6 |
| 2a) # and % of PATS | |
| 2b) Total # and % of employees participating in improvement projects | |
| 2c) Time allocated/production employee for process improvement | |
| 2d) # of suggestions/employee | |
| 2e) # and % of suggestions/employee implemented | |
| 3) The cost of quality measurement | 2.2.1 - #1<br>2.14.1.1 - #1 |
| 4) Measures that track the planning for quality measurement | 2.7.5.1 - #11 |
| 4a) # of short-term and long-term measurement objectives proposed per measurement cycle for each key process and support activity | |
| 4b) # of short-term and long-term measurement objectives met | |

[1]In fact, all the measures of chapter 2 can be listed in this section

per assessment cycle for each key process and support activity

4c) # of executive level, middle management and operational staff involved in the measurement planning process for each key process and support activity

4d) Adequacy of the representation of all stakeholder groups in the measurement planning process for each key process and support activity

4e) # of person-hours spent in the measurement planning process for each key process and support activity

4f) Consistency of the quality measurement objectives with the organizational vision of quality management development

5) Effectiveness of the organizational measurement process in terms of: 2.14.2.1 - #4
- enhancing employee ownership of the quality improvement process
- enhancing the communication in the organization with respect to quality related issues
- subsequent quality improvements in:
  - production/management processes
  - quality practices
  - training
  - supplier requirements
  - production standards
  - product quality
- the qualifications of the quality measurement personnel
- the procedures for reporting measurements
- the measurement administrative and operational procedures
- the statistical analysis of the measures
- the frequent and timely management review of quality measures
- the impact of quality measures on customer satisfaction
- accuracy of the quality measures
- simplicity of the quality measures

- employee ownership of the quality measures
- management support
- prototyping a quality measurement system
- incorporating all important measures and information into the QIS

6) # and % of the employees committed to quality measurement

7) The frequency of quality measurement for each key process and support activity

8) The # of new measures defined per measurement cycle for each key process and support activity

9) The accuracy of new measures defined per measurement cycle for each key process and support activity

10) The # of existing measures updated or deleted per measurement cycle for each key process and support activity

Descriptive Information

11) Procedures that describe structured group techniques that can be used to define quality measures; Such a procedure is described in chapter 3 of Document D [33]

12) Procedures that describe the quantitative evaluation approaches

13) Procedures for defining measurement scales for qualitative criteria such as: customer preference, customer satisfaction and employee satisfaction

14) Procedures that facilitate the definition of organizational and industry standards

15) Procedures that describe scoring procedures for quality management assessments

16) Procedures for identifying critical quality product characteristics

**2.6.1.2 Definitions of the Measures and their Data Requirements**

All the data required for these measures can be obtained from the quality assurance department.

1) Quality costs related to integrating quality into management activities: These refer to the internal costs incurred by the organization to integrate quality into management level activities. This is a preventive quality cost.

2) Measures of employee involvement in improvement of measurement procedures: The data for these measures can be obtained form the personnel and/or quality assurance departments.

2a) # and % of process action teams (PATS): The # of PATS involved in improvement of the quality measurement process and their % as compared to the total # of PATS operating in the organization give an indication of the importance of quality measurement.

2b) Total # and % of employees participating in improvement projects: Participation can be tracked either through the absolute # of employees participating or their relative %.

2c) Time allocated/employee for improvement: Improvement requires that adequate time is allocated per employee.

2d) # of suggestions per employee: As part of the improvement of quality measurement employee suggestions can lead to progress. If the # of suggestions/employee increase with time, this is an indication that employees are more willing to be involved.

2e) # and % of suggestions/employee implemented: An indicator of the effectiveness of employee participation is the total # of suggestions implemented per employee and its % as compared to the total # of suggestions made per employee.

3) The cost of quality measurement: This is the cost of defining, maintaining, updating, analyzing quality measures for the whole organization. Additionally, it involves the cost of designing and maintaining a quality information system

4) Measures that track the planning for quality measurement: An activity that is as important to quality management development as quality measurement requires planning. Some of the measures that track the effectiveness of this planning activity are defined subsequently.

4a) # of short-term and long-term measurement objectives proposed per measurement cycle for each key process and support activity: During the planning stage, a number of short-term and long-term objectives/goals will be proposed. During an effective planning session, both the # and the quality of these objectives/goals will be high.

4b) # of short-term and long-term measurement objectives met per assessment cycle for each key process and support activity: It is important to track the # of short-term and long-term objectives and goals actually achieved during each measurement cycle.

4c) # of executive level, middle management and operational staff involved in the measurement planning process for each key process and support activity: This planning effort requires the participation of all levels of management.

4d) Adequacy of the representation of all stakeholder groups in the measurement planning process for each key process and support activity: In addition to the representation of all management levels, it is important to have the representation of all stakeholder groups such the employees, customer and vendor representatives.

4e) # of person-hours spent in the measurement planning process for key processes and support activities: The effort required for this planning process can be tracked by the number of person- hours required to complete the planning.

4f) Consistency of the measurement objectives with the organizational vision of quality management development: The results of this planning process need to be consistent with the organization's quality improvement objectives. In fact, the quality improvement objectives can serve as an input to the planning process for quality management measurement.

5) Effectiveness of the organizational measurement process: There are a number of factors by which one can evaluate the effectiveness of the measurement process. Each of these factors can be formulated as a survey question with a common scale so as to be able to derive an aggregate score for effectiveness. Some of these are:

- enhancing employee ownership of the quality improvement process
- enhancing the communication in the organization with respect to quality related issues
- subsequent quality improvements in:
    - production/management processes
    - quality practices
    - training
    - supplier requirements
    - production standards
    - product quality
- the qualifications of the quality measurement personnel
- the procedures for reporting measurements
- the measurement administrative and operational procedures
- the statistical analysis of the measures
- the frequent and timely management review of quality measures
- the impact of quality measures on customer satisfaction
- accuracy of the quality measures
- simplicity of the quality measures
- employee ownership of the quality measures
- management support
- prototyping a quality measurement system
- incorporating all important measures and information into the QIS

6) # and % of the employees committed to quality measurement: In order to accomplish the quality measurement effectively, a large number of employees need

to participate. This measure tracks the absolute number of employees and their relative percentage.

7) The frequency of quality measurement for each key process and support activity: For each key process and support activity, in order to facilitate and track quality improvement, the quality measurement process needs to be repeated. This measure tracks the frequency of the quality measurement process for each key process and support activity.

8) The # of new measures defined per measurement cycle for each key process and support activity: Each time the quality measurement process takes place for each key process and support activity, new measures will be defined.

9) The accuracy existing measures defined per measurement cycle for each key process and support activity: The accuracy and the effectiveness of existing quality measures needs to be evaluated during the measurement process. Effectiveness can be measured in terms of how well the measure has contributed to quality control, assurance and improvement.

10) The # of existing measures updated or deleted per measurement cycle for each key process and support activity: Each time the quality measurement process takes place for each key process and support activity, existing measures will be updated or deleted if they have been proven not to be effective.

**2.6.1.3 Trends of Important Measures and Cost Contribution of Quality Measurement**

1) Trends of:

- # of short-term and long-term measurement objectives proposed per measurement cycle for each key process and support activity
- # of short-term and long-term measurement objectives met per assessment cycle for each key process and support activity
- # of executive level, middle management and operational staff involved in the measurement planning process for each key process and support activity
- # and % of the employees committed to quality measurement
- the frequency of quality measurement for each key process and support activity
- the # of new measures defined per measurement cycle for each key process and support activity
- the # of existing measures updated or deleted per measurement cycle for each key process and support activity

2) Quality measurement costs as a % of total quality costs: This is an indication of the level of commitment that the organization has with respect to quality measurement.

### 2.6.3 Management of Quality Data and Information

Definition: The classification, modeling, storage and retrieval of quality data and information so as to ensure effective communication and decision making with respect to quality.

#### 2.6.3.1 Overview of the Measures and the Associated Descriptive Information for Management of Quality Data and Information

Listing of Measures

| | Cross Reference Section - Measure # |
|---|---|
| 1) Accuracy and regularity of the data/ information input for quality measurement and evaluation | |
| 2) Maintenance cost of the Quality Information System (QIS) as a fraction of the total budget for computer support services | |
| 3) # of departments responsible for the irregular input of data and information into the QIS | |
| 4) Adequacy of the Data Base Management System (DBMS) technology | |
| 5) Hours spent per department or function gathering data and information used as input into the QIS | |
| 6) Adequacy of information with respect to the development/evaluation of plans and goals with respect to the following : | 2.8.2.1 - #30 |
| · meeting customer requirements<br>· improving process capability<br>· selecting organizations to benchmark<br>· determining competitive and benchmark data<br>· enhancing employee skill level<br>· improving supplier capability | |
| 7) # of times scheduled updates of data/ information is missed/omitted in terms of: | |
| · Extent and effectiveness of employee involvement | |

- Increase/decrease in levels of key indicators of employee well being and morale
- Customer satisfaction with respect to products and services relative to complaints, claims

8) Accessibility of the QIS

9) Response time of quality related queries — 2.8.2.1 - #7

10) Time span from gathering new data to the access of this data

11) Availability of quality control, quality assurance, quality improvement data per process (production/management) — 2.3.3.1 - #2h

12) # of techniques used for the rapid access of quality data and information

13) Frequency of timely and accurate updates of quality data and information — 2.5.3.1 - #1, 2.9.2.1 - #8

14) # of hardware facilities allocated to the management of quality data/information

15) #/% of personnel allocated to the management of quality data/information

16) #/% quality data/information of departments networked to QIS

17) Measures of employee involvement in the improvement of management of quality data and information — 2.7.1.1 - #6

   17a) # and % of PATS

   17b) Total # and % of employees participating in improvement projects

   17c) Time allocated/production employee for the improvement of the management of quality data and information

   17d) # of suggestions/employee

   17e) # and % of suggestions/employee implemented

18) The cost of designing and maintaining a quality information system — 2.2.1 - #1/#2/#3/#4, 2.14.1.1 - #1

19) Measures that track the planning for the management of quality data and information: — 2.7.5.1 - #11

- # of short-term and long term objectives proposed per planning cycle
- # of short-term and long-term objectives met per planning cycle
- # of executive level, middle management and operational staff involved in the planning for the management of quality data and information
- Adequacy of the representation of all stakeholder groups in the planning for the management of quality data and information
- # of person-hours dedicated to the planning for the management of quality data and information
- Consistency of the objectives with the organizational vision of quality management development

Descriptive Information

20) Documentation of the data-modeling approaches used

21) Documentation of the database management system used and its data access and update capabilities

### 2.6.3.2 Definitions of the Measures and their Data Requirements

The data for these measures can be obtained from the management information system department.

1) Accuracy and regularity of the data/information input required for quality measurement and evaluation: In order to efficiently carry out quality related activities/operations, it is important to have an accurate and regular flow of the required data and information. This measure will track whether or not the inflow of data to the QIS is accurate and suitable for measurement and evaluation purposes, and whether this input occurs at regular intervals.

2) Maintenance cost of the QIS as a fraction of the total budget for computer support services: It is important to keep track of this portion of the total expenses in order to assess the magnitude of the QIS maintenance cost, as compared to other computer support service expenses.

3) # of departments responsible for the irregular input of data and information into the QIS: Since irregular data input upsets the QIS update procedures, it is important to keep track of the departments responsible for the irregular input.

4) Adequacy of the DataBase Management Systems (DBMS) technology: This variable indicates the compatibility and suitability of the chosen DBMS technology relative to the existing data and computing environments.

5) Hours spent per department/function on gathering data and information used as input into the QIS: This measure indicates the total number of hours spent for data collection that is input to QIS.

6) Adequacy of information with respect to the development/evaluation of plans and goals for: meeting customer requirements, improving process capability, selecting organizations to benchmark, determining competitive and benchmark data, enhancing employee skill level, improving supplier capability: In order to efficiently manage the available data/information, it is important to assess the adequacy of the available information for development/evaluation of goals with respect to the previously mentioned categories. This measure helps determine whether or not there is need for additional information for a particular category.

7) # of times scheduled updates of data/information is missed/omitted: Regular QIS updates are extremely important. Some of the most important areas requiring frequent update are: employee involvement, employee well-being and morale and customer relations/services. In order to ensure availability of up to date information, it is important to track omissions, and try to minimize their occurrence.

8) Accessibility of the QIS: This measure will indicate whether or not the data stored in the QIS is readily available. In the long run, one could track the access speed of the DBMS.

9) Response time of quality related queries: A measure of effectiveness of any management information system is the response time of its queries. Once the quality data have been accumulated, it is necessary to model the data, determine the data collection mechanisms and design the underlying database management system. The most frequently used queries need to be analyzed so that a strategy is determined that minimizes their response time.

10) Time span from gathering new data to the access of this data: This is the total time span between gathering of new data and the point in time when this data is accessible to the users of the QIS.

11) Availability of quality control, quality assurance, quality improvement data per process (production/management): This variable takes into account the availability of quality control, assurance, control data for each production management process.

12) # of techniques used for rapid access of quality data and information: It is important to be able to access the desired data efficiently in the least time. This measure tracks the various techniques which facilitate this process.

13) Frequency of timely and accurate updates of quality data and information: For an up to date QIS, it is very important to perform timely, accurate and frequent updates. This measure records the frequency of such updates with respect to the data.

14) # of hardware facilities allocated to the management of quality data/ information: It is important to track the # and the different categories/types of computer hardware devices allocated to the management of quality data and information.

15) #/% of personnel allocated: It is the # or % of the work force allocated to the management of quality data and information.

16) #/% of departments networked to the QIS: It is important to track the #/% of departments which have been networked to the quality information system.

17) Measures of employee involvement in improvement of data and information management procedures:

17a) # and % of process action teams (PATS): The # of PATS involved in improvement of data and information management procedures and their % as compared to the total # of PATS operating in the organization give an indication of the importance of the management of quality data and information.

17b) Total # and % of employees participating in improvement projects: Participation can be tracked either through the absolute # of employees participating or their relative %.

17c) Time allocated/employee for improvement: Improvement requires that adequate time is allocated per employee.

17d) # of suggestions per employee: As part of the improvement of the management of data and information, employee suggestions can lead to progress. If the # of suggestions/employee increase with time, this is an indication that employees are more willing to be involved.

17e) # and % of suggestions/employee implemented: An indicator of the effectiveness of employee participation is the total # of suggestions implemented per employee and its % as compared to the total # of suggestions made per employee.

18) The cost of designing and maintaining a QIS: This involves the design and maintenance cost of the quality information system. This could be considered a preventive quality cost even though it facilitates the appraisal activities.

19) Planning for the management of quality data and information: It is important that the organization plan for the activities associated with the management of quality data and information. The following measures track the effectiveness of this planning process:

- # of short-term and long term objectives proposed per planning cycle
- # of short-term and long-term objectives met per planning cycle
- # of executive level, middle management and operational staff involved in the planning for the management of quality data and information
- Adequacy of the representation of all stakeholder groups in the planning for the management of quality data and information
- # of person-hours dedicated to the planning for the management of quality data and information
- Consistency of the objectives with the organizational vision of quality management development

#### 2.6.3.3 Trends of Important Measures and Cost Contribution of Management of Data and Information

1) Trends of:

- the response time of quality related queries
- the #/% of departments linked to the QIS
- increase/decrease in # hours for gathering data for QIS input
- #/% of personnel allocated to the management of quality data/information
- frequency of updates of quality data/information

2) QIS design and maintenance costs as a % of total quality costs: This is an indication of the level of commitment that the organization has with respect to the management of quality data and information.

### 2.6.4 Analysis of Quality Data and Information

Definition: The use of analytical techniques to detect unusual data and information and to provide accuracy for measurement of quality performance indicators.

#### 2.6.4.1 Overview of the Measures and the Associated Descriptive Information for the Analysis of Quality Data and Information

Listing of Measures

| | Cross Reference Section - Measure # |
|---|---|
| 1) Measures to track the cost associated with analysis of data and information: | 2.2.1 - #1<br>2.14.1.1 - #1 |
| 1a) Cost associated with the analysis of data and information as a percentage of the total budget for support services | |
| 1b) Total cost associated with the analysis of data and information | |
| 2) Measures to track the impact of data/ information analysis on quality improvement: | |
| 2a) # of organizational and quality changes suggested as a result of quality data/information analysis | |
| 2b) #/% of the suggested changes implemented | |
| 3) Time span between the commencement of analysis and reporting the results | |
| 4) Decrease/increase of time spent between commencement of the data analysis and obtaining the evaluations and results per analysis | |
| 5) #/% of employees qualified to handle complex data analysis and evaluation | |
| 6) # of changes/improvements implemented based on the analysis and evaluation of the relationship between quality costs and profitability | |

7) # of contracts with complete cost analysis that include:
   - actual versus standard contract cost comparison
   - impact of customer initiated changes on contract costs
   - cost changes which are communicated to managers and customers
   - potential cost overruns

8) # of methods used to analyze the data that represent the results of:
   - organizational planning
   - improvement of production processes and management activities

9) Measures to track the use of analytical techniques:

   9a) # of data/information analysis techniques used

   9b) frequency of use of each technique

10) Measures of employee involvement in improvement of data and information analysis procedures: 2.7.1.1 - #6

   10a) # and % of PATS

   10b) Total # and % of employees participating in improvement projects

   10c) Time allocated/production employee for process improvement

   10d) # of suggestions/employee

   10e) # and % of suggestions/employee implemented

Descriptive Information

11) Procedures for identifying outliers, leverage points, collinearity, measurement errors of quality data.

12) Relationships between quality costs, profitability, productivity, market share and price

13) Documentation on various analytical tools and their application areas

**2.6.4.2 Definitions of the Measures and their Data Requirements**

The data required for these measures can be obtained from the management information system department.

1) Measures to track the cost associated with analysis of data and information:

1a) Cost associated with the analysis of data and information as a percentage of the total budget for support services: It is important to keep track of the fraction of the total support services budget required for data and information analysis.

1b) Cost associated with the analysis of quality data and information: The quality cost incurred on behalf of all related procedures employed for analysis of quality data and information. This is a preventive quality cost.

2) # of organizational and quality changes a) suggested and b) implemented as a result of data/information analysis: The number of quality changes suggested and implemented as a result of data/information analysis is an indication of the impact and importance of this practice on quality improvement efforts.

3) Time span between the commencement of the analysis and the reporting of the results of the analysis: The analysis used to evaluate the quality data should be automated. This will allow more time for the development of action items based on this analysis.

4) Decrease/increase of time spent between commencement of the data analysis and obtaining the evaluations and results per analysis: This measure keeps track of the increase/decrease of measure 3 above, i.e., that of the time span between the commencement of the analysis and obtaining the evaluations and results of the data analysis.

5) #/% of employees qualified to handle complex data analysis and evaluation: It is important to enumerate the # and % of employees qualified to tackle complex data analysis and evaluation problems. This measure acts as an indicator for future hiring needs of additional qualified staff.

6) # of changes/improvements implemented based on the analysis and evaluation of the relationship between quality costs and profitability: This measure is an indication of data/information analysis contribution towards improved quality and increased profitability.

7) # of contracts with complete cost analysis: It is important to have a complete cost analysis for contracts. This measure keeps track of all contracts with the following elements:

- actual vs standard contract cost comparison
- impact of customer initiated changes on contract costs
- cost changes which are communicated to managers and customers
- potential cost overruns

8) # of methods used to analyze the data that represents organizational planning and quality improvement results: Quality planning and improvement are perhaps the two most important activities of quality management. Thus, it becomes important to analyze the results of the planning and improvement activities.

9) Measures to track the use of analytical techniques:

9a) # of data/information analysis techniques used: Is the total number of different types of analytical techniques used.

9b) Frequency of use of each technique: The measurement of how often a particular technique is used serves as an indicator of the importance of a specific technique.

10) Measures of employee involvement in improvement of data and information analysis procedures:

10a) # and % of process action teams (PATS): The # of PATS involved in improvement of analysis of data and information and their % as compared to the total # of PATS operating in the organization give an indication of the importance of the analysis of quality data and information.

10b) Total # and % of employees participating in improvement projects: Participation can be tracked either through the absolute # of employees participating or their relative %.

10c) Time allocated/production employee for the improvement of the data and information analysis: Improvement requires that adequate time is allocated per employee.

10d) # of suggestions per employee: As part of the improvement of the analysis of data and information, employee suggestions can lead to progress. If the # of suggestions/employee increase with time, this is an indication that employees are more willing to be involved.

10e) # and % of suggestions/employee implemented: An indicator of the effectiveness of employee participation is the total # of suggestions implemented per employee and its % as compared to the total # of suggestions made per employee.

**2.6.4.3 Trends of Important Measures and the Cost Contribution of Analysis of Data and Information**

1) Trends of:

- # of data/information analysis techniques used
- # of organizational and quality changes accomplished as a result of the analysis of quality data and information
- % of employees qualified to handle complex data analysis and evaluation
- # of contracts with complete cost analysis
- time spent between the commencement of the analysis and reporting of the results
- % of employees qualified to handle computer data analysis

2) The cost associated with the analysis of quality data & information as a % of the total quality costs: This is an indication of the level of commitment that the organization has with respect to the analysis of quality data and information.

## 2.7 EMPLOYEE INVOLVEMENT/BEHAVIORAL RECOGNITION/EMPLOYEE WELL-BEING/QUALITY EDUCATION AND TRAINING

### 2.7.1 Employee Involvement

Definition: The encouragement of all employees throughout the organization to become involved both individually and in teams so as to solve quality related issues in a timely and effective manner.

#### 2.7.1.1 Overview of the Measures and the Associated Descriptive Information for Employee Involvement

Listing of Measures

| | Cross Reference Section - Measure # |
|---|---|
| | 2.14.1.1 - #2 |
| 1) # and % of managers that encourage work group/ individual employee contributions to: | |
| a) action teams | |
| b) suggestion systems | |
| 2) Measures for the enhancement of team skills | |
| 2a) # of programs/workshops that enhance the skill level of employees/managers in terms of employee involvement | |
| 2b) #/% of employees per department involved in such programs | |
| 3) # of incentives offered to encourage employee involvement in quality improvement programs | 2.7.2.1 - #4<br>2.7.3.1 - #2 |
| 4) Total cost associated with all employee involvement programs (labor, material and overhead cost) | |
| 5) Cost associated with each improvement project for each process action team (PAT) | 2.2.1 - #1f |
| 6) Measures of employee involvement in PATS | 2.3.1.1 - #8<br>2.3.2.1 - #6<br>2.3.3.1 - #3<br>2.3.4.1 - #12<br>2.3.5.1 - #5<br>2.4.1 - #7<br>2.5.1.1 - #12 |

2.5.2.1 - #6
2.5.3.1 - #9
2.5.4.1 - #9
2.6.1.1 - #2
2.6.2.1 - #13
2.6.3.1 - #17
2.6.4.1 - #10
2.7.2.1 - #6
2.7.3.1 - #3
2.7.4.1 - #4
2.7.5.1 - #5
2.8.1.1 - #16
2.8.2.1 - #30
2.9.1.1 - #5
2.9.2.1 - #5
2.10.1 - #6
2.11.1 - #4
2.12.1 - #10
2.13.1 - #5
2.14.2.1 - #9
2.14.3.1 - #14
2.16.1 - #12
2.17.1 - #12
2.18.1 - #10
2.19.1 - #15
2.20.1 - #4
2.21.1 - #6

6a) # of PATS

6b) Total # and % of employee participating in improvement projects

6c) Time allocated/employee for quality improvement projects

6d) # of suggestions/employee

6e) # and % of suggestions/employee implemented — 2.7.2.1 - #2

6f) The impact of each improvement project on product quality, profitability, productivity, product cost, project schedule

7) Suggestion system measures

7a) # of suggestion systems

7b) # of suggestions/employee per suggestion system

| | |
|---|---|
| 7c) # and % of suggestions/employee implemented | 2.7.2.1 - #2 |
| 8) # and % of employees given more job responsibility/authority/innovation opportunities per employee category | 2.7.2.1 - #2<br>2.13.1 - #6<br>2.9.3.1 - #3<br>2.17.1 - #3 |
| 9) Effectiveness of the organization to foster:<br>· ownership of work 2.21.1 - #5<br>· willingness of managers to cooperate with employees<br>· empowerment of the work force to:<br>· innovate<br>· take risks and initiatives that can lead to quality improvement<br>· ensure that proactive quality<br>· improvement is part of the work culture | 2.6.1.1 - #5 |
| 10) The success of the organization to involve employees in:<br>· the public responsibility function<br>· resource conservation efforts<br>· planning (strategic and operational) process<br>· policy development process | 2.7.2.1 - #7<br>2.7.5.1 - #11c<br>2.16.1 - #7/#8<br>2.18.1 - #5/#8g |
| 11) The effectiveness of the organization to:<br>· facilitate and encourage group decision making over individual decision making | |
| 12) The adequacy of steps taken by the organization to:<br>· reinforce employee involvement as part of the company policy | 2.18.1 - #2 |
| 13) The effectiveness of the organization to achieve the following results in group activities:<br>· replacing the adversarial mentality with trust and cooperation<br>· developing the skills and leadership capability of individuals<br>· increasing employee morale and commitment<br>· fostering creativity<br>· helping people understand quality principles<br>· instilling quality principles into the corporate culture<br>· allowing employees to solve problems at the source immediately<br>· improving product quality and process productivity | 2.18.1 - #2<br><br><br><br><br><br><br><br>2.17.1 - #3 |

14) Measures linked to employee involvement results:
- increased job satisfaction
- increased group or unit effectiveness

15) # of employees involved in the strategic and operational planning process — 2.3.1.1 - #2a/#6a

Descriptive Information

16) Documentation of all the process improvement projects per PAT

17) Training materials related to employee involvement

**2.7.1.2 Definition of the Measures[2] and their Data Requirements**

The data required for the measures in this section can be found in the personnel department. A number of these measures (if not all of them) require that a survey question will be formulated for each measure and each survey question will be part of a questionnaire. This questionnaire would subsequently be distributed for response to the appropriate personnel within the organization.

1) # of managers encouraging work group/individual employee contributions to facilitate:

1a) Action teams: Employees from different departments are grouped together to focus on quality related problems/issues and suggest improvement initiatives. The heterogenous group structure will broaden the problem perspectives.

**Reference:** For further details refer to Evans and Lindsay, The Management and Control of Quality, Ch 11 (Appendix AA).

1b) Suggestion systems: A system set up to promote employee involvement, it encourages them to make a contribution through individual or group suggestions, the next step being their implementation (subsequent to a thorough analysis).

[2]As indicated earlier in this chapter, only a few of these measures re... the description of measurement techniques and/or additional concepts that ... used to derive them. Most of the measures are straightforward and/or sho... part of the existing cost accounting/management information system. For ... measures that require the description of measurement techniques and/or addit... concepts a reference will be made to a specific source that can be cons... Some sources are included in an Appendix at the end of this document.

2) Measures that track the enhancement of team skills

2a) # of programs/workshops that enhance the skill level of employees/ managers in terms of employee involvement: Quality management can be practiced through team efforts. Therefore, it is important that each employee/manager have team skills.

**Reference:** For further details refer to Evans and Lindsay, The Management and Control of Quality, Ch 11 (Appendix AA).

2b) #/% of employees per department involved in such programs: It is important to keep track of the #/% of employees in each department and also per employee category, who participate in the workshops and programs set up for their benefit.

3) # of incentives offered to encourage employee involvement in improvement programs: Incentives offered to employees will impact them positively in terms of their involvement in quality improvement.

4) The total cost associated with all employee involvement programs: There are administrative and direct labor costs associated with any organizational employee involvement program. This cost is a preventive quality cost.

5) Cost associated with improvement projects for each PAT: The cost in terms of labor, material and overhead for selecting and implementing improvement projects needs to be recorded. This cost is a preventive quality cost.

6) Measures of employee involvement in PATS: The most common form of employee involvement is through the process action teams (PATS). The analyst can obtain these measures per major employee category.

**Reference:** For further details refer to Evans and Lindsay, The Management and Control of Quality, Ch 11 (Appendix AA).

6a) # of process action teams (PATS): The # of PATS involved in quality improvement need to tracked.

6b) Total # and % of employees participating in quality improvement projects: Participation can be tracked either through the absolute # of employees participating or their relative %.

6c) Time allocated/employee for quality improvement projects: Improvement requires that adequate time is allocated per employee.

6d) # of suggestions per employee: As part of the planning process for quality improvement or in the implementation of process improvements employee suggestions can lead to progress. If the # of suggestions/ employee increase with time, this is an indication that employees are more willing to be involved.

6e) # and % of suggestions/employee implemented: An indicator of the effectiveness of employee participation is the total # of suggestions implemented per employee and its % as compared to the total # of suggestions made per employee.

6f) The impact of each improvement project on product quality, cost, project schedule, productivity, profitability: The % change in product quality, quality cost, manufacturing cost, productivity, profitability in the short-run (18 - 24 months) and the long-run (3 - 5 years) after an improvement project has achieved its results need to be tracked. This assumes that each of these organizational measures (product quality[3], quality cost[4], manufacturing cost, productivity[5], profitability) are defined and measured in the organization. This measure tracks the effectiveness of both the improvement process and employee involvement.

7) Suggestion system measures: Another form of employee involvement is participation in suggestion systems. Thus, it is important to measure the # of suggestion systems, the # of suggestions/employee made for each suggestion system and employee category and the % of these suggestions that have actually been implemented.

8) # and % of employees given more responsibility/authority/innovation opportunities per employee category: As employees are given more responsibility, authority, innovation opportunities then there is a higher probability that these employees will be motivated and will want to increase their participation in quality improvement.

9) Effectiveness of the organization to foster employee involvement: In order to facilitate employee involvement, the organization needs to foster the following:

- ownership of work
- willingness of managers to cooperate with employees
- empowerment of the work force to:
  - innovate
  - take risks and initiatives that can lead to quality improvement
  - ensure that proactive quality improvement is part of the work culture

10) The success of the organization to involve employees in important quality assurance and improvement functions such as:

- the public responsibility function
- resource conservation efforts

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[3]Aggregate product quality measure has been defined in section 2 measure 4a and section 2.8.2 measure 2 of Document D.

[4]Quality cost is defined in section 2.2.2 measures 1, 2, 3 and 4 of Doc. D.

[5]Productivity for the manufacturing and design engineering process defined in section 2.3.1.2, measure 1c and section 2.4.2, measure 1a respec of Document D.

- planning (strategic and operational) process
- policy development process

11) The effectiveness of the organization to promote the following group activities: Group employee involvement will be encouraged if group decision making is encouraged over individual decision making. Research shows that group decision is superior to individual decision as per The Management and Control of Quality, by Evans and Lindsay, ch 11 (Appendix AA).

13) The adequacy of steps taken by the organization to reinforce employee involvement as part of the company policy: The company policy sets the guidelines and emphasizes the practices important to the organization. Thus including employee involvement in the policy is an important step to making it an inherent mode of operation of the organization.

14) The effectiveness of the organization to achieve the following results in group activities:

- replacing the adversarial mentality with trust and cooperation
- developing the skills and leadership capability of individuals
- increasing employee morale and commitment
- fostering creativity
- helping people understand quality principles
- instilling quality principles into the corporate culture
- allowing employees to solve problems at the source immediately
- improving product quality and process productivity

15) Measures linked to employee involvement results:

- increased job satisfaction
- increased group or unit effectiveness

The benefit of increased involvement and participation of employees in a group increases the total output of the group in terms of quality and quantity of work.

16) # and % of employees involved in the strategic and operational planning process: In order for quality improvement to be successful, it is important to have representation from all employee categories in the strategic and operational planning process.

**2.7.1.3 Trends of Important measures**

1) Trends of:

- employee involvement
- involvement effectiveness measure
- cost associated with improvement projects
    - labor cost
    - material cost
    - overhead cost

- # of PATS
- Total # of employees participating in improvement projects
- Time allocated/employee for process improvement
- # of suggestions/employee
- # of suggestions/employee implemented
- # of suggestion systems
- # of suggestions/employee per suggestion system
- # of suggestions/employee implemented per suggestion system
- # of employees given more job responsibility/authority/innovation opportunities
- # of employees involved in the operational planning process per employee category

2) % of total quality costs attributed to:

- cost associated with improvement projects

### 2.7.4 Quality education and Training

Definition: The establishment of educational and training programs throughout the organization so as to increase the workforce's understanding and capability to deal with and improve quality.

#### 2.7.4.1 Overview of the Measures and the Associated Descriptive Information for Quality Education and Training

Listing of Measures

| | Cross Reference Section - Measure# |
|---|---|
| 1) Effectiveness of quality education and training in terms of facilitating process improvements[6] | 2.8.2.1 - #5b |
| 2) # and % of employees per employee category receiving education and training with respect to: | 2.3.1.1 - #9<br>2.3.2.1 - #7<br>2.3.3.1 - #4<br>2.3.4.1 - #13<br>2.13.1 - #7 |
| · process improvement<br>· team building<br>· quality definition and measurement<br>· quality management awareness training<br>· statistical methodology<br>  · design of experiments<br>  · regression analysis<br>  · data analysis<br>· quality assurance<br>· reliability engineering<br>· quality assessment<br>· planning for quality improvement | |
| 3) Numerical effectiveness measures of quality education and training: | |
| 3a) The average time spent on quality education and training per employee category | |
| 3b) The average cost per employee for quality education and training per employee category | 2.2.1 - #1d/#1c |

[6]This measure require that a survey question will be formulated as part of a questionnaire to be distributed for response to the appropriate personnel within the organization.

3c) The # of units of each organizational resource used for employee quality education and training

3d) The cost of each organizational resource used for employee quality education and training — 2.2.1 - #1e

3e) Efficiency measures for quality education and training

3f) The total cost of ongoing and new quality educational and training programs

4) Measures of process action team (PAT) employee involvement in the improvement of quality education and training — 2.7.1.1 - #6

4a) # and % of PATS

4b) Total # and % of employees participating in quality education and training improvement projects

4c) Time allocated/employee per quality education and training improvement project

4d) # of suggestions/employee per quality education and training improvement project

4e) # and % of suggestions/employee implemented per quality education and training improvement project

5) Time and money spent on the following planning activities for quality education and training: — 2.14.1.1 - #1

- assessment of the organization-wide quality educational level of the workforce
- assessment of the organization-wide quality educational needs of the workforce
- development of quality education methods
- the allocation of personnel and resources to perform quality education and training
- assessment of the number and types of quality education and training programs

6) #/% of managers involved in the planning of quality education and training programs

7) Time and money spent to form organization-wide process action teams for improvement of quality education and training

8) Effectiveness of the organization to keep pace with the most recent quality related training and education methods and practices available[7]

9) Effectiveness of the organization to improve the cooperation and communication organization-wide in terms of quality so as to facilitate quality awareness and education[37]

10) Effectiveness of the organization to motivate, facilitate and encourage the workforce to improve its quality education and training

11) Results obtained from quality education and training efforts in terms of improving:[37] 2.8.2.1 - #5b
   - employee quality awareness
   - responsiveness to quality issues
   - skill level
   - employee empowerment
     - average # of employee suggestions for quality related issues
     - employee authority/responsibility for quality related issues
   - products and services
   - customer satisfaction
   - process efficiency/productivity
   - employee decision making capability in terms quality issues
   - the cooperation and communication between employees and management

12) # of incentive/recognition awards given to employees and managers for enhancing their quality education and training capabilities

[7] This measure requires that a survey question will be formulated as part of a questionnaire to be distributed for response to the appropriate persons within the organization.

13) Adequacy of the organizational resources used for quality education and training[8]

14) Appropriateness and adequacy of the level of quality education and training for each employee in terms of:[38]
   - previous job experience
   - anticipated job rotation
   - previous formal educational background
   - previous self-instructional background

15) # and % of the employees that are involved in supplementary educational and training activities such as:
   - visits to other organizations
   - membership in professional societies
   - attendance of professional meetings
   - attendance of university-based continuing education programs
   - subscription to professional and trade publications

16) The # and % of quality education and training programs that have been offered in response to customer based quality concerns — 2.8.2.1 - 5b

Descriptive Information

17) Course/training materials with respect to:
   - process improvement
   - team building
   - quality definition and measurement
   - quality management awareness training
   - statistical methodology
     - design of experiments
     - regression analysis
     - data analysis
   - quality assurance
   - reliability engineering
   - quality assessment
   - planning for quality improvement

[8] This measure requires that a survey question will be formulated as part of a questionnaire to be distributed for response to the appropriate personnel within the organization.

### 2.7.4.2 Definitions of the Measures and their Data Requirements

The data required for the measures in this section can be obtained from the personnel department. A number of these measure (if not all of them) require that a survey question will be formulated for each measure and each survey question will be part of a questionnaire. This questionnaire would subsequently be distributed for response to the appropriate personnel within the organization.

1) Effectiveness of quality education and training in terms of facilitating process improvements: One of the prerequisites of process quality assurance and improvement is that the organization's employees will be continuously educated and trained. The term process is used in the context of this definition to represent both production and management value adding (transformation) activities. This measure tracks the effectiveness the organization to accomplish this task.

2) # and % of employees receiving education and training with respect to:
For each employee category it is important to track the # and % of employees receiving education and training per time period with respect to:

- process improvement
- team building
- quality definition and measurement
- quality management awareness training
- statistical methodology
    - design of experiments
    - regression analysis
    - data analysis
- quality assurance
- reliability engineering
- quality assessment
- planning for quality improvement

3) Numerical effectiveness measures of employee training and education: There are a number of numerical effectiveness measures that one can define in terms of education and training. The difficulty with these measures is in defining the output of the education and training process. One could define a number of surrogate output measures such as, the # of employee receiving training, the average time spent per employee, the exam scores per training sessions, etc. The output measures that should be used by the organization needs to be agreed upon by the important stakeholder groups.

3a) The average time spent on quality education and training per employee category: Of course tracking this measure does not indicate how well each employee has been trained or educated in term of quality.

3b) The average cost per employee for quality education and training per employee category: This cost is a preventive quality cost.

3c) The # of units of each organizational resource used in education and training: The main organizational resources are labor and overhead.

3d) The average cost of each resource used for employee training and education: If the average cost per resource used for retraining and education is known, then one could define an aggregate input index for education and training. This index would be the sum (over all the resources used) of the quantity of each resource times its average cost.

3e) Efficiency measure for education and training: Once the output measure(s) are agreed upon then the ratio of the output measure to the input index (defined in 3d) gives a measure of efficiency (productivity) of the quality education and training process.

4) Measures of employee involvement in the improvement of employee quality education and training:

4a) # and % of process action teams (PATS): The # of PATS involved in the improvement of quality education and training and their % as compared to the total # of PATS operating in the organization give an indication of the importance of improving employee quality education and training.

4b) Total # and % of employees participating in quality education and training improvement projects: Employee participation can be tracked either through the absolute # of employees participating or their relative %.

4c) Time allocated/employee per quality education and improvement project: Improvement requires that adequate time is allocated per employee per project.

4d) # of suggestions/employee per improvement project: As part of the planning for quality education and training improvement or in the implementation of these improvements, employee suggestions can lead to progress. If the # of suggestions/employee per project increase with time, this is an indication that employees are more willing to be involved.

4e) # and % of suggestions/employee implemented per quality education training improvement project: An indicator of the effectiveness of employee participation is the total # of suggestions implemented per employee per improvement project and its % as compared to the total # of suggestions made per employee.

5) Time and money spent on planning activities for quality education and training: As part of the planning for quality education and training a number of the following activities require both time and money:

- assessment of the organization-wide quality educational level of the workforce
- assessment of the organization-wide quality educational needs of the workforce
- development of quality education methods
- the allocation of personnel and resources to perform quality education and training
- assessment of the number and types of quality education and training programs

6) # and % of managers involved in the planning for quality education and training: Organizational commitment to quality can be demonstrated by the participation of management throughout the organization in terms of planning for quality education and training.

7) Time and money spent to form organization-wide process action teams for the improvement of quality education and training: In order to have employee participation, the organization needs to spent money and time to place these teams in operation.

8) Effectiveness of the organization to keep pace with the most recent quality related education and training methods and practices available: The organization needs to continuously benchmark its in-house quality education and training capabilities.

9) Effectiveness of the organization to improve (organization-wide) the cooperation and the communication in terms of quality so as to facilitate quality awareness and education: The premise of this measure is that if the organization increases its information sharing capability in terms of quality, then more employees/managers will feel the necessity to improve their quality related problem solving skills.

10) Effectiveness of the organization to motivate, facilitate and encourage the workforce to improve its quality education and training: The management's commitment and participation in quality improvement projects is a strong motivator for the remaining employees. Another motivator is the design of a reward mechanism for participating in quality improvement projects. One could list a series of other mechanisms by which the organization can motivate its employees. Once the appropriate level of motivation has been achieved, then the quality education and training will become a necessity.

11) Results obtained from quality education and training efforts in terms of improving employee quality capabilities: One would want to track the results achieved from quality education and training in terms of improving the following:

- employee quality awareness
- responsiveness to quality issues
- skill level
- employee empowerment
    - average # of employee suggestions for quality related issues
    - employee authority/responsibility for quality related issues
- products and services
- customer satisfaction
- process efficiency/productivity
- employee decision making capability in terms quality issues
- the cooperation and communication between employees and management

12) The # of incentive/recognition awards given to the employees and managers for enhancing their quality education and training: In terms of strengthening employee and management motivation, it is important to have awards that enhance the visibility of those who make an excellent effort in terms of augmenting their quality problem solving and decision making skills.

13) Adequacy of the organizational resources used for quality education and training: In addition to tracking the efficiency of the organizational resources used for quality education and training (as is accomplished with measure #3) , it is important to track the adequacy of these organizational resources.

14) Appropriateness and adequacy of the level of quality education and training for each employee: For each employee/manager, it is necessary to plan the development of each employee based on each individual's previous quality education history, i.e. one would have to consider:

- previous job experience
- anticipated job rotation
- previous formal educational background
- previous self-instructional background

15) # and % of the employees that are involved in supplementary educational and training activities: In addition to in-house quality education and training programs employees/managers can be involved in a number of other educational and training experiences such as:

- visits to other organizations
- membership in professional societies
- attendance of professional meetings
- attendance of university-based continuing education programs
- subscription to professional and trade publications

16) The # and % of quality education and training programs that have been offered in response to customer based quality concerns: If customer relations are mature, then it is possible to initiate quality education and training programs in response to specific customer quality issues and concerns.

#### 2.7.4.3 Trends of Important Measures and Cost Contribution of Quality Education and Training

1) Trends of:

- assessment scores on quality education and training
- the average quality education cost per employee
- the % of all employees receiving quality education and training

2) % of total quality costs attributed to:

- quality education and training cost

## 2.8 DETERMINING CUSTOMER REQUIREMENTS/CUSTOMER RELATIONS

### 2.8.1 Determining Customer Requirements

Definition: The systematic identification of customer preferences, needs, expectations that facilitates the determination of customer satisfaction. This information helps the organization manage its customer relations more effectively and in so doing increases the potential for growth and competitiveness.

#### 2.8.1.1 Overview of the Measures and the Associated Descriptive Information for Determining Customer Requirements

Listing of Measures

| | Cross Reference Section - Measure # |
|---|---|
| 1) Time required from: | |
| · order-to-receipt (standard product) | |
| · product definition-to-market (new) | |
| 2) Quality index of delivered product composed of: | 2.5.3.1 - #8 |
| 2a) accuracy of delivered shipment | |
| · % error in deliveries (shortages) | |
| · # of replaced/repaired items during installation | |
| · # of man-hours of service calls during installation | |
| 2b) reliability | 2.4.1 - #11a |
| · MTBF | |
| · MTTF | |
| · failure rate | |
| 2c) maintainability | 2.4.1 - #11c |
| · man-hours of required technical assistance after installation | |
| · MTTR | |
| 2d) availability | 2.4.1 - #11b |
| 2e) performance | |
| 2f) conformance | |
| 2g) durability | 2.4.1 - #12 |
| 2h) safety | 2.4.1 - #13 |

| | |
|---|---|
| 2i) usage cost | 2.4.1 - #18<br>2.8.2.1 - #11 |
| 3) Customer satisfaction index composed of the following elements: | 2.5.3.1 - #8<br>2.5.1.1 - #6a/#6b<br>2.8.2.1 - #15<br>2.12.1 - #5 |
| · total # of complaints | |
| · #/% of complaints that led to refunds | |
| · #/% of complaints that led to returns/replacements | 2.5.2.1 - #4e |
| · #/% of complaints that led to on-site repairs | |
| · warranty costs | 2.2.1 - #4c<br>2.4.1 - #10c |
| 4) #/% of customer complaints received with respect to: | 2.5.3.1 - #8<br>2.12.1 - #4 |
| · service standards | |
| · customer contact personnel | |
| 5) Repair measures | 2.5.3.1 - #8<br>2.8.2.1 - #4a |
| · MTTR | |
| · frequency of repairs | |
| · # of repairs per product | |
| · man-hours per repair request | |
| · cost of repair to customer | 2.2.1 - #4b |
| 6) Average response time relative to customer queries, complaints and suggestions | 2.5.1.1 - #6c<br>2.5.3.1 - #8<br>2.8.2.1 - #1/#7<br>2.9.1.1 - #3<br>2.9.2.1 - #3 |
| 7) The effectiveness of the complaint resolution process | |
| 8) #/% of customers gained/lost | 2.2.1 - #4f<br>2.5.3.1 - #8 |
| 9) Values of a customer satisfaction indicators (measures 1, 2, 3, 4, 5 6, 8 of this section) that can be used to compare to: | |
| · Principal competitors in market | |
| · Industry averages | |
| · Industry leaders | |
| · World leaders | |

10) # of new markets identified — 2.8.2.1 - #26

11) #/% of all employees and organizational departments that are knowledgeable of the customer expectations/requirements — 2.9.1.1 - #4

12) The average time required to communicate customer complaints to the responsible functional areas — 2.8.2.1 - #20; 2.9.1.1 - #3

13) # and % of managers involved in solving customer complaints — 2.9.1.1 - #4

14) # of customer visitation programs — 2.8.2.1 - #14

15) # and % of new product planning activities that both customer and producer participate — 2.4.1 - #6d; 2.8.2.1 - #12

16) Measures of employee involvement in the improvement of the determination of customer requirements/expectations — 2.7.1.1 - #1

   16a) # and % of PATS
   · # and % of joint stakeholder PATS

   16b) Total # and % of employees participating in improvement projects per employee

   16c) Time allocated/production employee for the improvement of determining customer requirements per employee

   16d) # of suggestions/employee

   16e) # and % of suggestions/employee implemented per employee

17) Cost of determining customer requirements/ expectations — 2.2.1 - #1; 2.14.1.1 - #1

Descriptive Information

18) Procedures that describe the processes and methods that are used to collect data and information for the purpose of determining the requirements and expectations of customers and to identify the market segments and customer groups important to the organization, including
   (a) The data collecting methods for example, surveys, interviews
   (b) The frequency with which data is to be collected
   (c) The data and information sources
   (d) The ways and means to assure data objectivity

19) Procedures to determine the different product and service characteristics and their relative importance to customers and customer groups

20) Procedures on how to determine a product brief that translates customer requirements to a preliminary set of design specifications

21) Procedures to determine the root cause of failures after analyzing the defective products returned by the customers and to take corrective actions that satisfy the customer

22) Procedures that establish a design function that translates customer needs from the product brief into technical specifications for materials, processes and products such that the translation results in a product that is producible, verifiable, and controllable under the current production capabilities, and provides customer satisfaction at an acceptable price.

**2.8.1.2 Definitions of the Measures[9] and their Data Requirements**

The data required for these measures can be obtained from the marketing department.

1) Time required from: a) order-to-receipt (standard product) and b) product definition-to-market (new product): This measure tracks the time it takes for a standard product to be received by the customer from when its order was placed and/or the time it takes to introduce a new product concept until the product reaches the market.

2) Quality index of delivered product: In order to understand customer requirements/expectations, it is important to track the quality of the product delivered to the customer. Each of the following components need to be weighted according to their relative importance. The customer in conjunction with the producer decide on the definition[10] of these weights ($w_j$ is the weight associated with each component that is described subsequently). Next a score $s_j$ is assigned by the customer (by answering a questionnaire or by defining an aggregate score based on a structured group process) to each component. An aggregate product quality score can be defined as $\sum (w_j s_j)$.

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[9]As indicated earlier in this chapter, only a few of these measures require the description of measurement techniques and/or additional concepts that can be used to derive them. Most of the measures are straightforward and/or should be part of the existing cost accounting/management information system. For those measures that require the description of measurement techniques and/or additional concepts a reference will be made to a specific source that can be consulted. Some sources are included in an Appendix at the end of this document.

[10]These weights can be defined by representatives of both organizations as part of structured group approach or in an unstructured fashion.

2a) Accuracy of the delivered shipment: The accuracy of the delivered shipment will be a function of the # of replaced/repaired items involved during installation, the shortages in a delivery, and the # of man-hours of service calls incurred during installation.

2b) Reliability: Is the probability will operate after t hours of use. For probability measure there is an equivalent failure rate measure (# of defects per unit of time). Additional reliability measures include the mean time between failures (MTBF) which is the mean between successive failures of a repairable product and the mean time to first failure (MTTF) which is the mean time to first failure of a repairable product. The computation of these measures depends on the assumption the analyst makes with respect to the product's life distribution. For a complex product, its reliability is a function of its subcomponents and parts.

**Reference:** For a detailed description of reliability figures of merit refer to Juran and Gryna, Quality Planning and Analysis, chs. 7,8 (Appendix I).

2c) Maintainability: Is the ease with which preventive and corrective maintenance can be achieved on a product. Its primary measures are the Mean Time to Repair (MTTR) and the # of man-hours of required technical assistance after installation.

2d) Availability: Is the ability of a product to perform its designated function when required for use. The availability of a product depends on how often failures occur (reliability) and how long it takes to fix any failures (maintainability) and the amount of maintenance support provided. The total time in operative state (uptime) is the sum of the time spent in active state and the time spent in the stanby state. The total time in the non-operative (downtime) is the sum of time spent under active repair plus the time spent waiting for spare parts. Availability is calculated as the ratio of operating time to operating time plus downtime. However, downtime can be viewed as total downtime (which includes the active repair time (diagnosis and repair), preventive maintenance time, and logistics time (time spent waiting for personnel, spare parts, etc.) When the total downtime is used, the resulting ratio is called operational availability $A_o$. When active repair time is used to express downtime, the resulting ratio is called "intrinsic availability" $A_i$. Thus, $A_o$ = (MTBF)/(MTBF + MDT) and $A_i$ = (MTBF)/(MTBF + MTTR) where MDT is the mean downtime and MTTR is the mean time to repair. These formulas can be used only under a number of assumptions

**Reference:** Refer to, Juran, Quality Control Handbook, pp. 13.40 - 13.45 (Appendix O).

2e) Product multiattribute performance index: Based on the definition of the new product performance characteristics, one could represent their relative importance with weights. A relative multiattribute performance index could be defined as $\Sigma w_j q_j$ where $w_j$ the weight associated with characteristic j and $q_j$ is the quantity of each characteristic per prod-

2f) New product conformance measures: It is important to be able to determine the conformance measures of a delivered product.

Statistical measures: If one takes a series of measurements for each quality characteristic for a number of products then: a) The mean of these measurements in relation to some predetermined target value defines the expected location ratio; b) Six times the standard deviation of these measurements compared to a predetermined tolerance width defines the capability ratio.

**Reference:** For more detail on the process capability measurement refer to Juran, Quality Control Handbook, pp. 16.14 - 16.35 (Appendix M).

# of defects/critical quality characteristic: For each delivery lot the # of defects/quality characteristic can be tracked.

2g) Product durability measures: The durability of a product depends in part on its reliability, maintainability and on the economic factors that may impact its existence. Every time a product fails and it is repairable, then an economic decision must be made concerning whether the product should be replaced or not. This decision will depend on the future operating costs of the product if it is repaired, the projected lifetime of the product, the acquisition cost of a new product and the minimum acceptable return that the organization uses to make replacement decisions. Two measures can be tracked. The first is the mean time to first failure and the second is the projected economic lifetime of the product allowing for repairs.

**Reference:** For more detail with respect to the calculations concerning projected economic lifetime refer to Canada & Sullivan, Economic Multiattribute Evaluation of Advanced Manufacturing Systems, pp. 197 - 204 (Appendix P).

2h) Product safety measures: It is important to indicate the # of potential hazards a product can cause and the projected risk/hazard (the probability that a hazard will occur). Hazard is any combination of parts, components, conditions, or changing set of circumstances which present an injury potential. MIL-STD-882A recognizes four levels of severity: catastrophic (may cause death or system loss); critical (may cause severe injury, severe occupational illness, or minor system damage); marginal (may cause minor injury, minor occupational illness or minor system damage); negligible (will not cause injury, occupational illness or system damage).

**Reference:** For further detail on product hazards and risks refer to Juran's, Quality Control Handbook, pp. 13.48 - 13.55 (Appendix K).

2i) Usage costs: One should record the product maintenance/usage costs These costs have labor, material and overhead components.

3) Customer satisfaction index: Another customer satisfaction index that is related to product defects can be tracked. Each of the following components need to be weighted according to their relative importance. The customer in conjunction with the producer decide on the definition of these weights ($w_j$ is the weight associated with each component that is listed subsequently). Next a score $s_j$ is assigned by the customer to each component. An aggregate product quality score can be defined as $\sum (w_j s_j)$. The components that can be tracked are:

- total # of complaints
- #/% of complaints that led to refunds
- #/% of complaints that led to returns/replacements
- #/% of complaints that led to on-site repairs
- warranty costs

4) #/% of customer complaints received with respect to: service standards and customer contact personnel: In addition to delivering a high quality product, the associated service should also be of high quality.

5) Repair measures: One might want to focus on the following aspects of product quality related to repair:

- MTTR (mean time to repair)
- frequency of repairs
- # of repairs per product
- man-hours per repair request
- cost of repair to customer

6) Average response time relative to customer queries, complaints and suggestions: It is important to measure and track the responsiveness of the producer in terms of customer queries, complaints and suggestions.

7) The effectiveness of the complaint resolution process: This is the ratio of the current average response time for complaint resolution to the base period average response time for complaint resolution. The base period is defined as the period when the organization responded well to customer complaints.

8) #/% of customers gained/lost: Total number and % of customers gained/lost over a specified period of time. This directly relates to the future viability of the organization.

9) Values of a customer satisfaction indicators (measures 1, 2, 3, 4, 5, 6 and 8 of this section) that can be used to compare to: principal competitors in market, industry averages, industry leaders, and world leaders: These indicators could be used to benchmark customer satisfaction regarding product quality, service quality, complaint resolution, and repair effectiveness.

10) # of new markets identified: One of the conditions of identifying new markets is to be able to determine customer needs, requirements and expectations.

11) #/% of all employees and organizational departments that are knowledgeable of the customer expectations/requirements: The more employees understand customer requirements/expectations then the higher the probability that the organization will be able to provide a high quality product and service.

12) The average time required to communicate customer complaints to the responsible functional areas: The quicker customer complaint information is communicated to the functional areas the higher the probability that current and future problems/defects will be solved effectively.

13) # and % of the managers involved in solving customer complaints: The majority of the managers should be in contact with the customer and should be part of the customer complaint resolution process.

14) # of customer visitation programs: The organization should establish customer visitation programs that involve the management and all other concerned employees so as to communicate and receive feedback from the customers on product/service quality.

15) # and % of new product planning activities that both customer and producer participate: This measure in part evaluate the effectiveness of the customer/ producer planning activities for new products and of the joint determination of significant new product characteristics.

16) Measures of employee involvement in improvement of the determination of customer requirements/expectations:

16a) # and % of process action teams (PATS): The # of PATS involved in the improvement of determining customer requirements and their % as compared to the total # of PATS operating in the organization give an indication of the importance of improving the determination of customer requirements/ expectations.

16b) Total # and % of employees participating in improvement projects: Participation can be tracked either through the absolute # of employees participating or their relative %.

16c) Time allocated/employee for improvement: Improvement requires that adequate time is allocated per employee.

16d) # of suggestions per employee: As part of the improvement of determining customer requirements/expectations, employee suggestions can lead to progress. If the # of suggestions/employee increase with time, this is an indication that employees are more willing to be involved.

16e) # and % of suggestions/employee implemented: An indicator of the effectiveness of employee participation is the total # of suggestions implemented per employee and its % as compared to the total # of suggestions made per employee.

17) Cost of determining customer requirements/expectations: It is the total cost associated with determining customer requirements/expectations. This is a preventive quality cost.

**2.8.1.3 Trends of Important Measures and the Cost Contribution of Determining Customer Requirements/Expectations**

1) Trends in:

- product quality index
- customer satisfaction index
- time required from order-to-receipt (standard product)
- time requires from product definition-to-market (new product)
- average response time to customer complaints
- #/% of customers gained/lost
- the average time required to communicate customer complaints to the responsible functional areas
- # and % of managers involved in solving customer complaints
- # of customer visitation programs
- # and % of new product planning activities that both customer and producer participate

2) % of total quality costs attributed to:

- Cost of determining customer requirements/expectations

3) Comparison to industry and world benchmarks in terms of:

- product quality index
- customer satisfaction index
- time required from order-to-receipt (standard product)
- time requires from product definition-to-market (new product)
- average response time to customer complaints
- #/% of customers gained/lost

## 2.10 STRATEGIC AND OPERATIONAL QUALITY PLANNING

Definition: A process that defines the organization's strategic and operational goals and objectives and proposes a plan that will help achieve these goals and objectives.

### 2.10.1 Overview of the Quantitative Measures and the Associated Descriptive Information for Strategic and Operational Quality Planning

Listing of Quantitative Measures

| | Cross Reference Section - Measure # |
|---|---|
| 1) Strategic/operational planning cycle for each key process and support activity<br>· # of days | 2.3.1.1 - #2d<br>2.4.1 - #6b |
| 2) Strategic or operational objectives for each key process and support activity | |
| 2a) # of short-term and long-term objectives proposed per planning cycle | 2.14.2.1 - #3a<br>2.3.1.1 - #2a<br>2.4.1 - #6a |
| 2b) #/% of quantitative (and their respective values) of the long-term and short-term objectives proposed per planning cycle | 2.3.1.1 - #6b |
| 2c) #/% of long-term and short-term objectives implemented per planning cycle | 2.3.1.1 - #2c<br>2.14.2.1 - #3b |
| 2d) #/% of long-term and short-term objectives successfully met per planning cycle | 2.3.1.1 - #6c |
| 2e) # of quality management system areas focused on by the strategic or operational planning process | |
| 2f) # of dollars dedicated for the improvement of each area of the quality management system over a five year period | |
| 2g) Time and dollars spent to gather and use meaningful information on the status of each quality management system area | |

3) Quality improvement projects per planning cycle (for each key process and support activity) — 2.12.1 - #2/#7

   3a) # of quality improvement projects proposed and % implemented per planning cycle — 2.4.1 - #6a

   3b) For each quality improvement project proposed and implemented define:
   - Its economic lifetime
   - Its lifetime benefits
   - Its resource requirements
   - Its economic lifetime operational costs
   - Its economic evaluation criterion (NPW, IRR, B/C, etc.)
   - Its multiattribute evaluation criterion

4) The strategic and operational quality planning commitment — 2.2.1 - #1e; 2.14.2.1 - #3c

   4a) frequency of the planning cycle

   4b) cost of planning

   4c) # of executive level, middle management and operational staff involved in the planning process

   4d) # of person-hours spent on the planning process

5) # of audits/evaluations/assessments of the planning process completed per planning cycle and their respective assessment score — 2.5.3.1 - #4a

6) Measures of employee involvement in the improvement of operational quality — 2.7.1.1 - #1

   6a) # and % of PATS

   6b) Total # and % of employees participating in improvement projects of strategic and operational planning per employee

   6c) Time allocated/production employee for the improvement of strategic and operational planning per employee

6d) # of suggestions/employee

6e) # and % of suggestions/employee implemented per employee

7) Consistency of the strategic and operational quality planning goals and objectives with the organizational vision of quality management system development

8) Adequacy of the resources committed per improvement project (binary variable) — 2.3.5.1 - #6b

9) Timeliness of the operational planning process so that it meets all scheduling requirements (binary variable) — 2.9.1.1 - #6

10) Consistency of the quality improvement objectives with the efficiency/productivity improvement objectives (binary variable)

11) Adequacy of the representation of the all stakeholder groups in the strategic and operational planning process (binary variable) — 2.14.2.1 - #3d

12) # of strategic and operational plans and goals met over a three to five year cycle

13) Measures that track the adequacy of market and competitive information for the quality planning process
- # of market surveys consulted
- # of competitors' studies consulted
- # of comparative evaluations used to establish the organization's position with respect to national and world competition

14) #/% of budget dollars allocated to innovation

15) #/% of budget dollars allocated for the modernization of equipment, new techniques to support quality improvement

16) #/% of budget dollars allocated for integrating all personnel to an easily accessible quality information system

17) #/% of budget dollars allocated to research, to analyze and to evaluate the necessity and nature of existing controls in the organizational system

18) #/% of quality plans defined to change, abolish or develop new controls in the organizational system to support the total quality improvement process

19) # and % of quality plans defined to ensure the transfer of responsibility and authority to the lower levels of the organization

20) # and % of quality plans defined to support the public responsibility function of the organization

21) #/% of budget dollars allocated for the public responsibility function of the organization

22) #/% of quality plans defined for developing a reward system, merit and rating system consistent with the quality values of the organization

23) #/% of budget dollars allocated to quality improvement in the strategic plan

24) #/% of budget dollars allocated to reinforce the quality values, goals and objectives throughout the organization

25) #/% of budget dollars and # of personnel dedicated to developing a quality measurement/information system that supports the quality improvement objectives

26) #/% of budget dollars and time dedicated to identify roadblocks to quality improvement

27) #/% of quality plans defined to overcome the roadblocks to continuous quality improvement

28) #/% of quality plans defined to involve all vendors in the quality improvement process and to develop strategies and policies for purchasing consistent with the continuous improvement process — 2.13.5 - #15

29) #/% of quality plans defined to improve customer satisfaction and service quality

Descriptive Information

30) Procedures for the strategic and operational planning process

31) Procedure for auditing the strategic and operational planning process

32) Procedures for evaluating the consistency of the planning process with the corporate vision and with the mission of continuous improvement

33) Procedures to determine the adequacy of the planning horizon to ensure the success of the planned goals and objectives

34) Procedures to determine the effectiveness of the strategic and operational planning process to focus on creating a value system, belief's, attitudes, culture and commitment supportive of a continuously improving quality management system

35) Procedures to determine the adequacy of the strategic plan to fulfill the organization's requirement in terms of personnel skills, new technology, equipment so as to continuously improve quality

36) Guidelines to evaluate the strategic and operational plan's adaptability to unforeseen changes in business conditions for example, in the marketplace, in the technology, etc.

37) Procedures to determine the strategic and operational plans effectiveness to increase the cooperation among all parts of the organization and to enhance the sharing of information throughout the organization

38) Procedures to evaluate the adequacy and appropriateness of the budget allocations for the quality improvement process in the strategic plan

39) Guidelines to evaluate the effectiveness of the strategic plan to include the measurement system so as to fully support the quality improvement process

40) Procedures to determine the effectiveness of the planning process to develop goals, objectives, mission and strategies and to include their key performance indicators

### 2.10.2 Definitions of the Measures[11] and their Data Requirements

The data required for these measures can be found in the organization's management information, cost accounting, and quality assurance departments.

**Reference:** For extensive details on the following measures refer to Sink and Tuttle, Planning and Measurement in your Organization of the Future, ch 1 (Appendix T) and Evans and Lindsay, The Management and Control of Quality, ch 6. (Appendix V).

1) Strategic planning cycle for each process: For each process, improvement will most likely take place after some strategic (implementation) planning for quality improvement has taken place. It is important to track the number of days required to complete the Strategic planning for each process that is being improved.

2) Strategic objectives: As a consequence of the strategic planning process, a number of long-term (2-6 years) objectives will be defined. A number of measures can be tracked such as:

- # of long-term objectives proposed per planning cycle
- # and % of quantitative long-term objectives proposed per planning cycle Also, it would be useful to record the specific values of the long-term quantitative objectives.
- # and % (of the total proposed) of long-term objectives implemented per planning cycle
- # and % (of the total implemented) of long-term objectives successfully met per planning cycle. This is an indication of the effectiveness of the actual quality improvement implementation

3) Quality improvement projects per planning cycle: As a direct outcome of the strategic planning process is the definition and assignment of improvement projects. Each project can address one or more strategic quality improvement objectives.

> 3a) The # of quality improvement projects and the % implemented per planning cycle: If the organization is beginning to do quality improvement, and has completed a thorough operational quality improvement exercise, then it probably can define quite a few number of quality improvement projects per process. However, given budget and resource constraints only a few of these projects are implemented per planning cycle.

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[11] As indicated earlier in this chapter, only a few of these measures require the description of measurement techniques and concepts that can be used to derive them. Most of the measures are straightforward and/or should be part of the existing cost accounting/management information system. For those measures that require the description of measurement techniques and concepts a reference will be made to a specific source that can be consulted and is included in an Appendix at the end of this document.

3b) Measures for quality improvement projects: For each quality improvement project proposed, a number of measures need to be defined. Its projected lifetime, start-up costs, projected lifetime operational costs and projected lifetime benefits provide enough information for the organization to compute its net present worth[12] (at the cost of capital for the organization), internal rate of return[13] and benefit/cost ratio[14] (at the cost of capital for the organization). Once the economic criteria are computed, then the organization can determine a multiattribute measure where other criteria are defined per project (for example, customer satisfaction, implementation time, implementation difficulty, etc). The relative importance of each criterion needs to be decided by the organization as well as the contribution of each project to each criterion.[15] Thus, the multiattribute score of each project is computed as $\Sigma w_j t_j$ where $w_j$ is the weight associated with criterion j (the indicator of its relative importance) and $t_j$ is the contribution of each project to criterion j normalized to a common scale.

**Reference:** To review the methodology of weighing different characteristics or attributes and then normalize them to a common scale refer to Canada & Sullivan, Economic Multiattribute Evaluation of Advanced Manufacturing Systems, ch. 8 (Appendix E). This methodology could be used to rank projects. Refer also to section 3.5 of Document C [34].

4) The strategic planning costs per planning cycle: The cost of strategic quality improvement planning is a preventive quality cost.

5) # of audits/evaluations/assessments of the planning process and the respective score for each assessment: The effectiveness of the strategic quality improvement process needs to be evaluated. Either separately or in conjunction with the a quality management assessment, the strategic improvement planning process can be evaluated. The outcome of this assessment would be an assessment score and suggestions for process improvements.

6) Measures of employee involvement in improvement of strategic quality improvement planning:

6a) # and % of process action teams (PATS): The # of PATS involved in improvement and their % as compared to the total # of PATS operating in

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[12]Net present worth = Present worth (Benefits - Costs) over the lifetime of the project.

[13]Internal rate of return is computed when the net present worth equals zero.

[14]Present worth of the benefits over the present worth of the costs is the benefit cost ratio.

[15]The contribution of each project to each criterion is translated into normalized common scale for all criteria. Usually this is a 0-100 scale

the organization give an indication of the importance of improving strategic quality improvement planning.

6b) Total # and % of employees participating in improvement projects: Participation can be gauged either through the absolute # of employees participating or their relative %.

6c) Time allocated/employee for improvement: Improvement requires that adequate time is allocated per employee.

6d) # of suggestions per employee: As part of the planning process or in the implementation of process improvement employee suggestions can lead to progress. If the # of suggestions/employee increase with time, this is an indication that employees are more willing to be involved.

6e) # and % of suggestions/employee implemented: An indicator of the effectiveness of employee participation is the total # of suggestions implemented per employee and its % as compared to the total # of suggestions made per employee.

7) Consistency of strategic quality improvement objectives with strategic planning quality improvement goals and objectives and quality management system development: In order to ensure consistency between the operational quality improvement goals and the strategic quality improvement goals for quality management system development, it is probably necessary to have someone who participated in the strategic planning process to also participate in the operational planning process. This is a 0-1 variable, 1 indicating consistency and 0 non-consistency.

**Reference:** See Document C [34], chapter 2 for strategic quality planning.

8) Adequacy of the resources committed per improvement project: It is important to ensure that adequate resources are committed to each project. This is a 0-1 variable, 1 indicating adequacy and 0 inadequacy.

9) Consistency of quality improvement objectives with efficiency/ productivity improvement objectives: In the short-term quality improvement objectives may have an effect of decreasing productivity of the process. In the long-run, quality and productivity gains should be move in the same direction. Thus, it is important to analyze the ramifications of quality improvement objectives in terms of productivity improvement. This is a 0-1 variable, 1 indicating consistency and 0 non-consistency.

10) Consistency of the quality improvement objectives with the efficiency/ productivity improvement objectives (binary variable), the binary variable takes a value of 0 or 1. 0 indicates inconsistency and 1 indicates consistency.

11) Adequacy of the representation of the important stakeholder groups in the strategic quality improvement process: In the PAT formulated for process improvements (per project) it is important to have representation

from all the stakeholder groups. This is a 0-1 variable, 1 indicating adequacy and 0 inadequacy.

12) # of strategic and operational plans and goals met over a three to five year cycle: This measure gives an indication of the effectiveness of the planning process quality management implementation process.

13) Measures that track the adequacy of market and competitive information for the planning process: Market and competitive information is an essential input to the quality planning process. Measures that track the adequacy of the market an d competitive information are:

- # of market surveys consulted
- # of competitors' studies consulted
- # of comparative evaluations used to establish the organization's position with respect to national and world competition.

14) #/% of budget dollars allocated to innovation: In order to accomplish quality improvement, innovation needs to be encouraged and funded.

15) #/% of budget dollars allocated for the modernization of equipment and new techniques to support quality improvement: Quality improvement cannot be accomplished without investment in new equipment and facilities. These investment decisions need to be evaluated economically using multiattribute decision making techniques.

**Reference:** See Canada and Sullivan, Economic Multiattribute Evaluation of Advanced Manufacturing Systems, chs. 8 (Appendix E) and 10 (Appendix EE) for an extensive discussion on multiattribute decision making techniques.

16) #/% of budget dollars allocated for integrating all personnel to an easily accessible quality information system: An accessible information system facilitates employee discretion, authority and responsibility for quality improvement at all levels of the organization. It facilitates the decision making ability of those making critical choices about quality improvement.

17) #/% of budget dollars allocated to research, to analyze and to evaluate the necessity and nature of existing controls in the organizational system: This measure assumes the following:

- That controlling a process is important
- That unnecessary controls need to be removed
- That it is important to ensure that the right process parameters are being controlled
- That controls have a significant impact on the process and product quality

18) #/% of quality plans defined to change, abolish or develop new controls in the organizational system to support the total quality improvement process: Controls may need to change for a number of reasons For example, the increase in education and training of the workforce

coupled with a deeper understanding of the quality principles can make a lot of process controls unnecessary.

19) # and % of quality plans defined to ensure the transfer of responsibility and authority to the lower levels of the organization: It is important to be able to transfer quality improvement responsibility and authority to the lower levels of the organization.

20) # and % of quality plans defined to support the public responsibility function of the organization: Public responsibility is an important element of the quality improvement process. A part of the planning should be dedicated to the public responsibility of the organization.

21) #/% of budget dollars allocated for the public responsibility function of the organization: Public responsibility is an important element of the quality improvement process. A part of the planning should be dedicated to the public responsibility of the organization.

22) #/% of quality plans defined for developing a reward system, merit and rating system consistent with the quality values of the organization: A reward system that is inconsistent with the quality values of the organization can become a major roadblock to all quality improvement efforts.

23) #/% of budget dollars allocated to quality improvement in the strategic plan: It is important to keep track of all monetary resources that are allocated to quality improvement as part of the strategic planning process.

24) #/% of budget dollars allocated to reinforce the quality values, goals and objectives throughout the organization: Quality culture needs to be continuously reinforced.

25) #/% of budget dollars and # of personnel dedicated to developing a quality measurement/information system that supports the quality improvement objectives: One of the premises of quality development is that quality improvement cannot be accomplished without the support of a sophisticated quality measurement/information system.

26) #/% of budget dollars and time dedicated to identify roadblocks to quality improvement: A portion of the quality improvement budget needs to be allocated to the identification of quality improvement roadblocks. These are usually organizational or process in nature.

27) #/% of quality plans defined to overcome the roadblocks to continuous quality improvement: Once the roadblocks to quality improvement are identified, the organization needs to remove them in a timely manner.

28) #/% of quality plans defined to involve all vendors in the quality improvement process and to develop strategies and policies for purchasing consistent with the continuous improvement process: A major part of the quality planning process needs to be dedicated to improving vendor relations.

29) #/% of quality plans defined to improve customer satisfaction and service quality: A major part of the quality planning process needs to be dedicated to improving customer relations.

### 2.10.3 Trends of Important Measures and Cost Contribution of Strategic and Operational Planning and Other Analytical Approaches

1) Benchmarking: Analyze the organization's projected quality levels for the next two to five years and compare them with those of competitors.

2) Trends of:

- # of employees represented in the planning process per employee category
- # of years per planning cycle
- # of long-term goals and short-term objectives proposed per planning cycle
- # of data types proposed per planning cycle
- # of quantitative long-term goals and short-term objectives proposed per planning cycle
- # of long and short-term objectives implemented per planning cycle
- # of long and short-term objectives successfully met per planning cycle
- # of quality improvement projects proposed and implemented per planning cycle
- the strategic/operational planning costs per planning cycle
- # of audits/evaluations/assessments of the planning process completed per planning cycle
- #/% of budget dollars allocated to innovation
- #/% of budget dollars allocated for the modernization of equipment, new techniques to support quality improvement
- #/% of budget dollars allocated for integrating all personnel to an easily accessible quality information system
- #/% of budget dollars allocated to research, to analyze and to evaluate the necessity and nature of existing controls in the organizational system
- #/% of quality plans defined to change, abolish or develop new controls in the organizational system to support the total quality improvement process
- # and % of quality plans defined to ensure the transfer of responsibility and authority to the lower levels of the organization
- # and % of quality plans defined to support the public responsibility function of the organization
- #/% of budget dollars allocated for the public responsibility function of the organization
- #/% of quality plans defined for developing a reward system, merit and rating system consistent with the quality values of the organization
- #/% of budget dollars allocated to quality improvement in the strategic plan
- #/% of budget dollars allocated to reinforce the quality values, goals and objectives throughout the organization
- #/% of budget dollars and # of personnel dedicated to developing a quality measurement/information system that supports the quality improvement objectives

- #/% of budget dollars and time dedicated to identify roadblocks to quality improvement
- #/% of quality plans defined to overcome the roadblocks to continuous quality improvement
- #/% of quality plans defined to involve all vendors in the quality improvement process and to develop strategies and policies for purchasing consistent with the continuous improvement process
- #/% of quality plans defined to improve customer satisfaction and service quality

3) % of total quality costs attributed to:

- the strategic planning costs per planning cycle

## 2.11 LEADERSHIP

Definition: Leadership is defined as the activity of guiding, directing, facilitating, encouraging and motivating given the organizational responsibility and authority.

### 2.11.1 Overview of the Measures and the Associated Descriptive Information for Leadership

Listing of Measures

| | Cross Reference Section - Measure # |
|---|---|
| 1) Senior executive leadership | 2.21.1 - #2 |
| 1a) #/% of strategic quality improvement objectives initiated in terms of: | |
| · process improvements<br>· quality management development<br>· resource allocation<br>· education and training<br>· customer relations<br>· vendor relations<br>· human resource management<br>· public responsibility<br>· quality assurance<br>· quality measurement<br>· benchmarking<br>· documentation<br>· management of quality data | 2.8.2.1 - #13 |
| 2) Leadership with respect to development of next generation products: | |
| · # of hours spent in product planning efforts<br>· # of dollars and resources allocated by the leadership for next generation products<br>· involvement of leadership (hours per month) to enable the organization to benchmark product features and quality so as to maintain leadership in the marketplace | |
| 3) Organizational leadership in terms of: | 2.21.1 - #2 |
| 3a) # of quality awareness meetings and seminars attended and organized | |

3b) # of improvement actions initiated

3c) # of PAT teams in which leadership participated

3d) # of organizational checks and controls removed

3e) # of surveys initiated and conducted

3f) # of working sessions initiated to improve customer relations

3g) # of initiatives to determine customer needs — 2.8.2.1 - #13

3h) # of hours spent to alter organizational policies so as to achieve customer satisfaction

3i) # of successful quality improvement projects leadership participated in

3j) # of hours spent and # of programs initiated for human resource management

3k) # of reviews initiated to evaluate the quality improvement process

3l) # of evaluations with respect to quality functions for the organizational leadership

4) Measures of employee involvement in the improvement of leadership — 2.7.1.1 - #6

4a) # and % of PATS

4b) Total # and % of employees participating in improvement projects per employee

4c) Time allocated/production employee for the improvement of leadership per employee

4d) # of suggestions/employee

4e) # and % of suggestions/employee implemented per employee

Descriptive Information

5) Description of how senior executive leadership champions quality management in terms of:

   - communication with others
   - increasing the quality knowledge base
   - personal involvement

6) Guidelines to determine the adequacy of surveys undertaken by the leadership to gather information on the difficulties, roadblocks and factors that hinder process and product quality improvement

7) Procedures to evaluate the effectiveness of the leadership to initiate and sustain quality attitudes, beliefs and values in the organization

8) Guidelines to determine the effectiveness of the leadership to encourage, motivate, reward and recognize team spirit, innovation, work ownership, initiative, high quality workmanship, sincerity and honesty at work, leadership and adoption of quality culture in the organization

9) Guidelines to evaluate the effectiveness of the leadership to:

   a) Open communication channels among all levels and departments of the organization

   b) Ensure easy access to all relevant information to all employees

   c) Create an atmosphere of trust and teamwork among the different levels of employees and departments by replacing organizational divisions

   d) Set an example of embracing principles of the quality philosophy and championing its cause visibly and sincerely

   e) Effectively communicate to the whole organization the continuous quality improvement paradigm and ensure that projects are accomplished to educate and train all employees

   f) Develop objectives, goals and a corporate mission and communicate it in a clear, understandable and purposeful manner to the entire organization

   g) Ensure that employee morale is high, that a sense of autonomy exists within the workforce, that there is a sense of pride, that self esteem is present and that all situations are dealt with fairly

   h) Delegate authority and responsibility to the lower levels of the organization

i) Effectively integrate vendors and suppliers into the continuous quality improvement process

j) Ensure that customer feedback channels are established and appropriate responsiveness to complaints and customer needs is achieved

k) Ensure that the all tasks are totally integrated and coordinated among departments and employees

l) Form action teams and task forces and ensure their proper facilitation and success

m) Document and establish procedures and methods concerning all jobs and ensure that this information is provided to the person doing that job

n) Ensure that appropriate performance measures are developed to monitor quality improvement

o) Maintain up-to-date technology and equipment and benchmark performance of product and services against all competitors

p) Focus on public responsibility issues and ensure that organization's leadership in the community

**2.11.2 Definitions of the Measures[16] and their Data Requirements**

The data required for these measures can be obtained from the quality information system.

1) Senior executive leadership with respect to strategic quality improvements initiatives (#/% of strategic quality objectives initiated): It is important to gauge the level, strength and influence of leadership at the senior executive level with respect to strategic goals setting in terms of:

- process improvements
- quality management development
- resource allocation
- education and training
- customer relations
- vendor relations
- human resource management
- public responsibility

[16]As indicated earlier in this chapter, only a few of these measures require the description of measurement techniques and/or additional concepts that can be used to derive them. Most of the measures are straightforward and/or should be part of the existing cost accounting/management information system. For those measures that require the description of measurement techniques and/or additional concepts a reference will be made to a specific source that can be consulted. Some sources are included in an Appendix at the end of this document.

- quality assurance
- quality measurement
- benchmarking
- documentation
- management of quality data

**Reference**: An example of a survey that tracks employee responses to leadership is the DOD Productivity and Quality Self-Assessment Guide (Appendix F).

2) Development of next generation products: One of the important activities of senior executive leadership is to promote new products/services. The extent of their commitment can be tracked by how many resources are dedicated to such an effort and how well new products have been planned. This involves measuring:

- # of hours spent in product planning efforts
- # of dollars and resources allocated by the leadership for next generation products
- involvement of leadership (hours per month) to enable the organization to benchmark product features and quality so as to maintain leadership in the marketplace

3) Organizational leadership in terms of:

3a) # of quality awareness meetings and seminars attended and organized: This measure tracks the # of meetings and seminars attended and organized to create quality awareness and to communicate the quality culture within the organization and to actively guide the quality improvement effort.

3b) # of improvement actions initiated: The total # of improvement actions initiated and dollars allocated on suggestions and ideas contributed by the organizational staff.

3c) # of PAT teams in which leadership participated: # of action teams the leadership actively and effectively participated in.

3d) # of organizational checks and controls removed: # of controls and checks removed that overregulate the quality management system.

3e) # of surveys initiated and conducted: # of surveys conducted organization wide by the leadership to determine roadblocks to successful job completion, safety hazards at the workplace, security problems, lack of facilities and other grievances of the employees.

3f) # of working sessions initiated to improve customer relations: # of working sessions, meetings, seminars and effective actions initiated to focus on the priority of customer service and satisfaction.

3g) # of initiatives to determine customer needs: # of effective initiatives and actions taken to solicit customer feedback on quality related issues and to determine customer needs.

## 2.13 VENDOR/CONTRACTOR RELATIONS

Definition: The technological, economic, quality management relations between the buyer and contracting organizations that have a common objective of providing quality products/services to the buyer organization

### 2.13.1 Overview of the Measures and the Associated Descriptive Information for Vendor/Contractor Relations

Listing of Measures

| | Cross Reference Section - Measure # |
|---|---|
| 1) Contracted product/service specifications | 2.5.1.1 - #7<br>2.17.1 - #10 |
| 1a) Value of each quality characteristic (specification) per product and/or service as defined by the buyer and agreed upon by the contractor such as:<br>• quantity of final product<br>• ability (reliability, maintainability, availability)<br>• durability<br>• conformance to quality requirements of the product/service defined by the buyer (degree of conformance such as % defectives for example)<br>• cost/price | 2.2.1 - #3a |
| 1b) Multiattribute quality indicators per product using the information in item #1a | |
| 2) Other performance characteristics | 2.5.1.1 - #7<br>2.17.1 - #11 |
| 2a) Performance characteristics that need to be met by each contractor, such as:<br>• timeliness of delivery<br>• field service<br>• a score of the quality management capabilities (this requires a complete assessment of the quality management capabilities of each contractor) | |
| 2b) A multiattribute measure of each contractor using the information in item #2a. | |

3) Quality related issues

- 3a) # of quality issues that have arisen between contractor and buyer per time period
- 3b) % of quality issues that have been resolved between contractor and buyer per time period
- 3c) Timeliness in terms of resolving each quality issue

4) Cost measures

- 4a) Cost of contractor monitoring (assessment) over the life of the contract — 2.2.1 - #1c
- 4b) Cost of planning for improvement of contractor relations — 2.2.1 - #1c
- 4c) Cost of improving contractor relations
- 4d) Cost of awarding contracts
  - CBD writeup
  - Source selection plan
  - RFP writeup
  - Proposal evaluation
- 4e) Cost (over a period of time) to both the buyer and contractor of each quality issue that has arisen between contractor and buyer
- 4f) Actual versus budgeted contract costs

5) Measures of buyer/contractor involvement in the improvement of buyer/contractor relations such as: — 2.7.1.1 - #1, 2.17.1 - #3

- 5a) # and % of PATS
  - # and % of joint stakeholder PATS
- 5b) Total # and % of employees participating in improvement projects per employee
- 5c) Time allocated/production employee for process improvement per employee
- 5d) # of suggestions/employee

5e) # and % of suggestions/employee implemented per employee

| | |
|---|---|
| 6) # and % of employees for each organization that have been given the authority to define and solve quality issues that involve both organizations per time period | 2.7.1.1 - #3<br>2.17.1 - #3 |
| 7) # and % of employees in contractor relations per organization that have been certified and/or trained in process improvement, quality management, quality assurance, team building, assessment and strategic and operational planning | 2.7.4.1 - #2 |
| 8) # and % of communication channels between the two organizations used per time period to communicate quality issues | 2.17.1 - #1 |
| 9) Frequency of audits/assessments used to evaluate the buyer/contractor relationship | 2.5.3.1 - #2<br>2.5.1.1 - #4a<br>2.17.1 - #4 |
| 10) Parameters of incoming material acceptance sampling plans | 2.5.1.1 - #7<br>2.5.2.1 - #2e/#3 |

10a) For each attribute sampling plan include:
- Lot size, sample size, maximum allowable number of defectives, producer's and consumer's risk, acceptable quality level and lot tolerant percent defective.

10b) For each variable sampling plan include:
- Lot size, sample size, maximum allowable number of defectives, upper and/or lower quality limits, producer's and consumer's risk, acceptable quality level and lot tolerant percent defective.

10c) For each sampling plan identify the sampling frequency over time and the location of the testing (contractor or buyer organization)

| | |
|---|---|
| 11) Assessment scores of all major subcontracting organizations in terms of their quality management capabilities | 2.5.3.1 - #4d |

12) Frequency of contractor certification — 2.5.1.1 - #7c

13) # of rewards/acknowledgements per contractor for quality improvements per time period

14) # of joint vendor quality related meetings, seminars, and working sessions

15) Measures that track the planning for vendor/contractor relations:

- # of short-term and long term objectives proposed per planning cycle
- # of short-term and long-term objectives met per planning cycle
- # of executive level, middle management and operational staff involved in the planning for vendor/contractor relations — 2.10.1 - #28
- Adequacy of the representation of all stakeholder groups in the planning for vendor/contractor relations
- # of person-hours dedicated to the planning for vendor/contractor relations
- Consistency of the objectives with the organizational vision of quality management development

Descriptive Information

16) Procedures for contractor selection and certification

17) Procedures and criteria for contractor assessment in terms of their quality management capabilities (see Document A [35])

18) Procedures for including quality management requirements in the procurement process

19) Procedures for identifying and communicating buyer requirements to the contractor

20) Procedures for identifying and resolving quality issues between the buying and contracting organization (such as, nonconforming materials, etc.)

21) Instructions for the interpretation of:
- inspection plans
- controls
- quality records

22) Inspection, testing and inspection procedures of incoming products

23) Procedures for the design of experiments

24) Guidelines to determine the effectiveness of vendor/contractor assessments that evaluate quality attitudes, values, beliefs, and culture

25) Guidelines to determine the effectiveness, regularity and consistency of the organization to evaluate all contractors in terms of process quality, product quality and the quality management system

26) Guidelines to determine the effectiveness of the organization to involve all affected departments and personnel in both organizations in the procurement process, for example:
   a) accounting
   b) operations management
   c) purchasing
   d) planning
   e) engineering
   f) production/manufacturing
   g) quality assurance

27) Guidelines to determine the effectiveness of the organization to maintain open communication channels with the contractor's organization such that all employees involved in the procurement process can communicate directly and quickly with their counterparts to resolve any questions and problems

28) Guidelines to determine the effectiveness of the organization to assist the contractor in resolving technical problems, quality issues and productivity issues; This may be in terms of giving feedback, offering suggestions, sharing technical know-how, participating in problem solving teams at the contractor's site etc.

29) Guidelines to determine the effectiveness of the organization to follow a structured contracting process, for example:
   a) The buyer gives details of his requirements (including product and service specifications and other relevant particulars to invite quotes from potential suppliers)

   b) The potential suppliers submit quotes

   c) The buying organization reviews all the quotes; All valid quotes are considered and site visits to contractors' plants are organized; This requires a team review; The review team consists of representatives of all departments affected by the procurement process

   d) This step involves a team site visit; The team reviews and surveys the quality management system of the potential suppliers

   e) In this step the team orders and receives engineering samples. These samples are completely evaluated and tested by the quality and engineering function of the buying organization; Samples are fully documented and technical report is generated; Along with the

24) Guidelines to determine the effectiveness of vendor/contractor assessments that evaluate quality attitudes, values, beliefs, and culture

25) Guidelines to determine the effectiveness, regularity and consisten of the organization to evaluate all contractors in terms of proc quality, product quality and the quality management system

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   b) operations management
   c) purchasing
   d) planning
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   e) In this step the team orders and receives engineering sampl These samples are completely evaluated and tested by the qual and engineering function of the buying organization; Samples fully documented and technical report is generated; Along with

maintenance of such indicators and triggers must be done in conjunction with the contractors

33) Guidelines to determine the effectiveness of the organization to establish and maintain formal and informal norms, procedures and methods to resolve quality disputes with the contractors

34) Procedures to evaluate the effectiveness of the organization to establish and maintain an accurate and easily accessible information system for the contractors; This information system must carry all relevant information to help the contractor fulfill it's obligation of providing quality products and services to the organization, for example:

   a) Information on tools, techniques, products and services known to the organization that may enhance contractor operations

   b) Information on the procedures, policies and regulations of the organization that may concern the contractors

   c) Information on long and short term goals of the organization relevant to the contractors to help them keep pace with the buyer

35) Guidelines to determine the effectiveness of the organization to motivate and encourage contractors to provide superior products and services and to continuously improve quality; Some of the ways the organization may do this is by:

   a) Giving quality awards

   b) Incentives and recognition

   c) Giving larger and long term contracts

**2.13.2 Definitions of the Measures[32] and their Data Requirements**

The data required to define these measures can be found in the quality assurance department.

**Reference: For more detail on all of these measures please to Juran, Juran's Quality Control Handbook, ch. 15 (Appendix Z).**

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[32]As indicated earlier in this chapter, only a few of these measures require the description of measurement techniques and/or additional concepts that can be used to derive them. Most of the measures are straightforward and/or should be part of the existing cost accounting/management information system. For those measures that require the description of measurement techniques and/or additional concepts a reference will be made to a specific source that can be consulted Some sources are included in an Appendix at the end of this document.

1) Contracted product/service specifications: For each contract there a number of product specifications/requirements that the contractor needs to satisfy.

1a) Value of each quality characteristic: The value of each quality characteristic defines the product specification. For each product, there are a number of performance requirements that can be also translated into conformance, ability and durability requirements.

Product quality performance characteristics: Based on the needs of the buying organization, a number of quality performance characteristics can be defined per product type ordered from the contracting organization. Quality product characteristics can be measured either as continuous variables (measured on an interval scale) or as discrete variables (0-1 scale). These characteristics can be classified as critical, major and minor. The determination of how a characteristic can be classified depends on the characteristic and its relationship to user requirements. The % of critical, major and minor characteristics can give some indication as to the amount of effort that will be required to accomplish incoming quality assurance. For those characteristics that are non-testable and critical the design of the quality assurance procedures is more difficult.

Reliability: Is the probability will operate after t hours of use. For probability measure there is an equivalent failure rate measure (# of defects per unit of time). Additional reliability measures include the mean time between failures (MTBF) which is the mean between successive failures of a repairable product and the mean time to first failure (MTTF) which is the mean time to first failure of a repairable product. The computation of these measures depends on the assumption the analyst makes with respect to the product's life distribution. For a complex product, its reliability is a function of its subcomponents and parts.

**Reference:** For a detailed description of reliability figures of merit refer to Juran and Gryna, Quality Planning and Analysis, chs. 7,8 (Appendix I).

Availability: Is the ability of a product to perform its designated function when required for use. The availability of a product depends on how often failures occur (reliability) and how long it takes to fix any failures (maintainability) and the amount of maintenance support provided. The total time in operative state (uptime) is the sum of the time spent in active state and the time spent in the stanby state. The total time in the non-operative (downtime) is the sum of time spent under active repair plus the time spent waiting for spare parts. Availability is calculated as the ratio of operating time to operating time plus downtime. However, downtime can be viewed as total downtime (which includes the active repair time (diagnosis and repair), preventive maintenance time, and logistics time (time spent waiting for personnel, spare parts, etc.) When the total downtime is used, the resulting ratio is called operational availability, $A_o$. When active repair time is used to express downtime, the resulting ratio is called "intrinsic availability" $A_i$. Thus, $A_o$ = (MTBF)/(MTBF + MDT) and $A_i$ = (MTBF)/(MTBF + MTTR) where MDT is the mean downtime and MTTR

is the mean time to repair. These formulas can be used only under a number of assumptions (see, Juran's Quality Control Handbook, p. 13.42 (Appendix O)).

**Reference:** Refer to, Juran, Quality Control Handbook, pp. 13.40 - 13.45 (Appendix O).

Maintainability: Is the ease with which preventive and corrective maintenance can be achieved on a product. Its primary measure is Mean time to Repair (MTTR).

Product durability measures: The durability of a product depends in part on its reliability, maintainability and on the economic factors that may impact its existence. Every time a product fails and it is repairable, then an economic decision must be made concerning whether the product should be replaced or not. This decision will depend on the future operating costs of the product if it is repaired, the projected lifetime of the product, the acquisition cost of a new product and the minimum acceptable return that the organization uses to make replacement decisions. Two measures can be tracked. The first is the mean time to first failure and the second is the projected economic lifetime of the product allowing for repairs.

Product conformance measures: It is important to be able to define the conformance measures necessary to assure the quality of the incoming products.

> Statistical measures: If one takes a series of measurements for each quality characteristic for a number of products then: a) The mean of these measurements in relation to some predetermined target value defines the expected location ratio; b) Six times the standard deviation of these measurements compared to a predetermined tolerance width defines the capability ratio. The location and capability ratios can be defined for each quality characteristic.
>
> **Reference:** For more detail on the process capability measurement refer to Juran, Quality Control Handbook, pp. 16.14 - 16.35 (Appendix M).
>
> # of defects/ quality characteristic: Given the incoming lot, the acceptable # of defects/characteristic can be defined.

Quantity, Cost, Price of each incoming product: Along with the quality characteristics per product it is important to define the quantity, cost, price requirements per contractor.

1b) Multiattribute quality indicator per product: Based on all the characteristics defined in 1a per product, one could represent their relative importance with weights. A relative multiattribute quality index could be defined as $\Sigma w_j q_j$ where $w_j$ the weight associated with characteristic j and $q_j$ is the quantity of each characteristic per product

2) Other performance indicators: Outside the definition of the product requirements, there could be a series of other contractor performance requirements specified in the contract.

2a) Performance requirements that need to be met by each contractor: These may include measures of:

- timeliness of delivery
- field service (such as courtesy of repair personnel, logistics support, etc. This information can be obtained through a survey issued during the contract and a score of field service can be obtained.)
- a score of the quality management capabilities (this requires a complete assessment of the quality management capabilities of each contractor)

**Reference:** See, Document A [35].

2b) A multiattribute measure of each contractor using the information in item #2a: Based on all the performance requirements defined in 2a per contractor, one could represent their relative importance with weights. A relative multiattribute quality index could be defined as $\Sigma w_j s_j$ where $w_j$ the weight associated with performance requirement j and $s_j$ is the score of each contractor per performance requirement.

3) Quality related issues: There are a number of quality issues that arise on any given contract. Some important measures that need to be tracked per contract include:

- # of quality issues that have arisen between contractor and buyer per time period
- % of quality issues that have been resolved between contractor and buyer per time period
- Timeliness in terms of resolving each quality issue

4) Cost measures: The cost of contractor relations needs to be measured over the life of each contract. Relevant cost measures include:

- Cost of contractor monitoring (assessment) over the life of the contract; This involves the cost of performing assessment(s) over the life of the contract. These audits or assessments can be with respect to process capability, product performance, quality management capabilities. This cost can be classified as an appraisal cost.
- Cost of planning for improvement of contractor relations; This cost can be classified as a preventive cost.
- Cost of improving contractor relations; This cost can be classified as a preventive cost.
- Cost of awarding contracts; This cost is not a direct quality cost. However, it is a good indicator of the cost of the effort necessary for awarding a contract.
- Cost (for the duration of the contract) to both the buyer and contractor of each quality issue that has arisen between contractor and buyer; This cost can relate to product related quality issues

and procedural quality issues. This cost is an external failure cost for the contractor.

- Actual versus budgeted contract costs;

5) Measures of buyer/contractor involvement in the improvement of buyer/contractor relations such as:

5a) # and % of process action teams (PATS): The # of PATS involved in improvement of vendor relations and their % as compared to the total # of PATS operating in the organization give an indication of the importance of improving buyer/contractor relations. Also, it is important to track the # and % of the joint buyer/contractor PATS.

5b) Total # and % of employees participating in improvement projects: Participation can be tracked either through the absolute # of employees participating or their relative %.

5c) Time allocated/employee for improvement: Improvement requires that adequate time is allocated per employee.

5d) # of suggestions per employee: As part of the improvement vendor/contractor relations, employee suggestions can lead to progress. If the # of suggestions/employee increase with time, this is an indication that employees are more willing to be involved.

5e) # and % of suggestions/employee implemented: An indicator of the effectiveness of employee participation is the total # of suggestions implemented per employee and its % as compared to the total # of suggestions made per employee.

6) # and % of employees for each organization (buying and producing) that have been given the authority to define and solve quality issues that involve both organizations per time period: This is a measure of empowerment for the employees in both the buying and contracting organizations to define and solve quality related issues.

7) # and % of employees in contractor relations receiving education and training with respect to:

For the employees involved in contractor relations (including contracting officers) it is important to track the # and % of employees receiving education and training per time period with respect to:

- process improvement
- team building
- quality definition and measurement
- quality management awareness training
- statistical methodology
- quality assurance
- reliability engineering
- quality assessment
- planning for quality improvement

8) The # of communication channels open to both organizations that can be used to communicate quality issues: The communication channels can be formal (planning meetings, PATS for process improvements, audit teams, # of participants hooked up to a common computer network, formal organizational channels, etc.) and informal. In order to get a rough estimate of the informal communication channels one could issue a survey requesting this type of information from both organizations.

9) Frequency of audits/assessments used to evaluate the contractor/buyer relationship: Over the life of the contract, a series of assessments/audits can take place. The frequency of these audits will vary from contract to contract.

10) Parameters of incoming product acceptance sampling plans:

10a) Attribute sampling plans: For each attribute sampling plan one needs to know the lot size, sample size, maximum allowable number of defectives per sample (if the number of defectives found per sample exceeds this number, then the lot is rejected), producer's risk (the probability that the lot produced at some stage of the manufacturing process gets rejected by the sampling plan even though its is of adequate quality), consumer's risk (the probability that a production stage accepts an in-process lot even though it is not of adequate quality), acceptable quality level (the % defective that represents adequate quality over the long run or the % defective incoming quality that corresponds to the producer's risk), lot percent tolerant defective (the % defective incoming quality that corresponds to the consumer's risk).

**Reference:** For a discussion of acceptance sampling plans refer to Hansen and Ghare, Quality Control and Application, chs. 9, 14 (Appendix H).

10b) Variable sampling plans: For each variable sampling one needs to know the lot size, sample size, maximum allowable number of defectives per sample (if the number of defectives found per sample exceeds this number, then the lot is rejected), the upper and lower quality limits, producer's risk (the probability that the lot produced at some stage of the manufacturing process gets rejected by the sampling plan even though its is of adequate quality), consumer's risk (the probability that a production stage accepts an in-process lot even though it is not of adequate quality), acceptable quality level (the % defective that represents adequate quality over the long run or the % defective incoming quality that corresponds to the producer's risk), lot percent tolerant defective (the % defective incoming quality that corresponds to the consumer's risk).

**Reference:** For a discussion of acceptance sampling plans refer to Hansen and Ghare, Quality Control and Application, chs. 9, 14 (Appendix H).

10c) Sampling frequency for each sampling plan: For each sampling plan it is important to track the sampling frequency and where the sampling plan will be executed (buyer or contractor organizations).

11) Assessment scores of all subcontracting organizations: For major/critical components subsystems that are purchased by the contractor from other subcontractors, the contractor needs to perform product, process and quality management system assessments. The scores of these assessments can be reported to the buying organization.

> **Reference:** Document A [35] for quality management system assessment; Juran & Gryna, Quality Planning and Analysis, ch 22 for product/process audits (Appendix S).

12) Frequency of contractor certification: It may be necessary to some contractors to be certified (in terms of process capability, quality management, etc.). The frequency of certification and certification requirements need to be defined.

13) # of rewards/acknowledgments per contractor for quality improvements per time period: Beyond the formal contract monitoring, it is important to track the # of rewards and informal acknowledgements per contractor over the life of the contract. This allows for improving contracting relations beyond the legal contracting requirements.

14) # of joint vendor quality meetings, seminars and working sessions: These meetings are organized by the organization with its vendors/contractors to ensure exchange of ideas, promote quality understanding and solve quality or related problems.

15) Planning for vendor/contractor relations: It is important that the organization plan for the activities associated with vendor/contractor relations. The following measures track the effectiveness of this planning process:

- # of short-term and long term objectives proposed per planning cycle
- # of short-term and long-term objectives met per planning cycle
- # of executive level, middle management and operational staff involved in the planning
- Adequacy of the representation of all stakeholder groups in the planning for vendor/contractor relations
- # of person-hours dedicated to the planning for vendor/contractor relations
- Consistency of the objectives with the organizational vision of quality management development

### 2.13.3 Trends of Important Measures and Cost Contribution of Vendor Relations

1) Trends of:

- test results per product for each contractor
- multiattribute quality indicators per product purchased
- timeliness of delivery
- field service
- a score of the contractor's quality management capabilities

- % of quality issues that have been resolved between contractor and buyer per time period
- timeliness in terms of resolving each quality issue
- cost of contractor monitoring over the life of the contract
- cost of planning for improvement of contractor relations
- cost of improving contractor relations
- cost of awarding contracts
- # and % of employees for each organization that have been given the authority to define and solve quality issues that involve both organizations per time period
- assessment scores of all major subcontracting organizations in terms of their quality management capabilities
- frequency of contractor certification

2) % of total quality costs attributed to:

- cost of contractor monitoring over the life of the contract
- cost of planning for improvement of contractor relations
- cost of improving contractor relations
- cost of awarding contracts

## 2.21 QUALITY CULTURE

Definition: The creation of attitudes and behavior patterns in the organization according to quality management values, so as to increase team spirit, stakeholder satisfaction, and the facilitation of continuous improvement.

### 2.21.1 Overview of the Measures and Associated Descriptive Information for Quality Culture

Listing of Measures

| | Cross Reference Section - Measure # |
|---|---|
| 1) Measures that track the effectiveness of the organization to instill quality values throughout the organization<br>· # of audits, evaluations and surveys designed and implemented to determine the existing quality values of the organization<br>· $'s and person hours allocated to educate, train and create awareness among employees as to the quality values<br>· Consistency of the quality plans, actions and projects undertaken with the organization's quality values | |
| 2) Measures that track the effectiveness of the organization in communicating and monitoring the quality culture<br>· # of meetings, seminars and training sessions per month to communicate the quality culture<br>· $'s and person hours allocated for the above mentioned effort<br>· # and % of upper management representatives participating in the above mentioned activities<br>· The effectiveness of the organization to choose and implement appropriate means of communication for different organizational levels, divisions so as to ensure that the quality culture can be effectively communicated and monitored at all levels of the organization | 2.11.1 - #3<br><br><br><br>2.11.1 - #1 |

3) Measures that track the effectiveness of the organization to develop methods, techniques and specific programs to increase ownership of quality values and culture
   - # of rewards and incentives for ownership of quality values and culture
   - $'s allocated for the above effort — 2.2.1 - #1i
   - # and % of employees given recognition for their adopting and adhering to the quality values
   - # of meetings and seminars organized that focus on the benefits of the quality culture
   - # and % of top management involved in the above effort
   - # and % of employees trained and educated in the quality management principles

4) Effectiveness to define the quality dimensions and standardize the terminologies used regarding quality

5) Effectiveness to create a quality culture by stressing the following activities:
   - spreading awareness of quality throughout the organization
   - ensuring evidence of upper management leadership
   - self-development of the workforce
   - empowerment of the workforce
   - participation of employees in the management and decision making process for quality improvement — 2.7.1.1 - #9
   - recognition, rewards and incentives for quality performance, acceptance and practice of quality culture

6) Measures of employee involvement in the enhancement of quality culture — 2.7.1.1 - #6

   6a) # and % of PATS

   6b) Total # and % of employees participating in improvement of research projects

   6c) Time allocated/employee for the improvement of quality culture

   6d) # of suggestions/employee

   6e) # and % of suggestions/employee implemented

Descriptive Information

7) Procedures to:
- Determine quality values
- Communicate the different aspects of the quality culture throughout the organization
- Design ways and means to reinforce the adoption of the quality culture throughout the organization, such as frequent seminars and talks convincing the employees that quality is important and the new paradigm does work
- Ensure ownership of quality values for all employees
- Determine the actions that demonstrate the importance of the quality culture to the organization and ensure the visibility of those actions
- Define product quality and its dimensions

**2.21.2 Definitions of Measures and their Data Requirements**

The data for these measures can be obtained from the quality assurance department or from the quality information system.

**Reference:** For more details on these measures please refer to Juran and Gryna, Quality Planning and Analysis, ch. 8 (Appendix U).

1) Measures that track the effectiveness of the organization to instill quality values throughout the organization: These are:
- # (and their respective assessment scores) of the audits, evaluations and surveys designed and implemented to determine the existing quality values of the organization
- $'s and person hours allocated to educate, train and create awareness among employees as to the quality values of the organization
- Consistency of quality plans, actions and projects undertaken with the quality values; The quality actions that the organization undertakes should be consistent with its quality values.

2) Measures that track the effectiveness of the organization in communicating and monitoring the quality culture: These are:
- # of meetings, seminars and training sessions per month to communicate the quality culture
- $'s and person hours allocated for the above mentioned effort
- # of upper management representatives participating in the above mentioned activities
- The effectiveness of the organization to choose and implement appropriate means of communication for different organizational levels, divisions so as to ensure that the quality culture can be effectively communicated and monitored at all levels of the organization

3) Measures that track the effectiveness of the organization to develop methods, techniques and specific programs to increase ownership of quality values and culture: These are:

- # of rewards and incentives given to teams, work groups and/or individuals that demonstrate ownership of quality values and culture
- $'s allocated for the above effort
- # and % of employees given recognition for their adopting and adhering to the quality values.
- # of meetings and seminars organized that focus on the benefits of the quality culture to the organization, customers and workers etc.,i.e, to all stakeholders. These meetings and seminars should also promote understanding of the underlying principles and philosophies and help the employees feel secure with them.
- # and % of top management involved in the above effort
- # and % of employees trained and educated in the quality management principles

4) Effectiveness of the organization to define the quality dimensions and standardize the terminologies used regarding quality: In order to facilitate the adaptation of quality culture throughout the organization it is necessary for the employees to understand the quality dimensions and the standardized terminologies used to describe all quality concepts.

5) Effectiveness to create a quality culture by stressing the following activities:

- spreading awareness of quality throughout the organization
- ensuring evidence of upper management leadership
- self-development of the workforce
- empowerment of the workforce
- participation of employees in the management and decision making process for quality improvement
- recognition, rewards and incentives for quality performance, acceptance and practice of quality culture

These six activities coupled with the methodologies and structure for quality development bring about a change to quality culture in such areas such as:

Awareness: One could track the following measures:

- Effectiveness of the organization to communicate quality awareness in the appropriate language to a particular organizational level. For example, for all management levels, the awareness of quality is best achieved by the use of monetary concerns. By highlighting threats to sales and opportunities of cost reduction are effective ways to create awareness of quality management.
- # of meetings and seminars held per year on a company wide basis to promote quality awareness
- # of PATS formed to spread quality awareness
- # of newsletters on quality, quality items on meeting agendas, announcements on quality by top management, conferences and "interest arousers" (for example, letters from customers on performance issues) all help spread awareness and interest in quality management.
- Effectiveness of the organization to maintain and reinforce quality awareness. Measurement of quality related activities at all levels of the organization is an extremely important reinforcement tool. One could track:
  - $'s and person hours allocated each year for the purpose of quality measurement
  - # of measurement criteria and techniques developed and implemented organization wide

Management leadership: One could track the following measures:

- # of top level management serving on quality councils, quality meet-

and conferences
- # of the above mentioned councils, quality meetings and seminars organized by top management per year
- # of quality policies established by top management
- $'s and person hours allocated ( as a percentage of total management work hours) to formulate quality policies and develop plans
- Effectiveness of the top management to establish and deploy quality goals and objectives
- # of person hours allocated to establish goals and objectives
- $'s and person hours spent to assess present quality baseline and the given resources, roadblocks and required tasks to fulfill the quality goals and objectives
- Effectiveness of the organization (leadership) to ensure the availability of the resources and their proper utilization
- Effectiveness of the leadership to provide quality training
    - $'s allocated for quality training
    - Person hours spent to evaluate and choose appropriate training methods for a given training program
    - # of PATS formed to help the training effort
- Effectiveness of the upper management to visibly participate and support all quality related efforts
    - % of top management time spent to fulfill quality related tasks

Additionally, the areas of participation, recognition and reward, empowerment, and training are dealt with in section 2.7.1, 2.7.2, 2.7.3, and 2.7.4. respectively.

6) Measures of employee involvement in the enhancement of quality culture:

6a) # and % of process action teams (PATS): The # of PATS involved in enhancement projects and their % as compared to the total # of PATS operating in the organization give an indication of the importance of enhancing quality culture.

6b) Total #/% of employees participating in the enhancement of quality culture: Participation can be tracked either through the absolute # of employees participating or their relative %.

6c) Time allocated per employee for the enhancement of quality culture Improvement requires that adequate time is allocated per employee.

6d) # of suggestions per employee: As part of the enhancement of quality culture, employee suggestions can lead to progress. If the # of suggestions/employee increase with time, this is an indication that employees are more willing to be involved.

6e) # and % of suggestions per employee implemented: An indicator of the effectiveness of employee participation is the total # of suggestions implemented per employee and its % as compared to the total # of suggestions made per employee.

**2.21.3 Trends of Measures**

1) Measures of:

- # of audits, evaluations and surveys designed and implemented to determine the existing quality values of the organization
- $'s and person hours allocated to educate, train and create awareness among employees as to the quality values
- # of meetings, seminars and training sessions per month to communicate the quality culture
- # and % of employees given recognition for their adopting and adhering to the quality values
- # of meetings and seminars organized that focus on the benefits of the quality culture
- # and % of top management involved in communicating quality values
- # and % of employees trained and educated in the quality management principles

# APPENDIX C

## RESULTS OF WORKSHOP ACTIVITIES WITH "DELTA" EMPLOYEES TO DEVELOP PROTOTYPE QUESTIONNAIRE FOR VENDOR/CONTRACTOR MEASUREMENT DATA

## Defining of Appropriate Quality Measures for Vendor Relations

Based on the listing and the definitions of the quality measures of Appendix B the following measures were combined into a comprehensive set defined by the customer.

| Item # | Measures of Appendix B | Examples/Additional Information |
|---|---|---|
| 1 | 25/11 | Used to determine degree of control over vendors; Knowledge of relationship with vendors and used to rate vendors |
| 2 | 1/19/18 | First article test result; Incoming inspection result and customer cost |
| 3 | 28/14 | Used to determine organizational commitment to vendors; Can be used in Navy program review |
| 4 | 3 | The timeliness of the identification of a quality issue and its correction; the # of recurrences of a quality issue; the # of waivers and deviations requested; the # of value engineering change proposals (VECP); Relationship and commitment to vendors |
| 5 | 3 | same as item #4 |
| 6 | 7 | The # and variety of certification programs; for example. Raytheon's different programs at different organizational levels |
| 7 | 1/19/18 | same as item #2 |
| 8 | 2 | Used for award fee decisions; Input to vendor rating system and used to trigger vendor contractor meetings. working sessions and PATs |
| 9 | 9/14/24 | Quality costs associated with vendor quality audits. Used to impact award decision and planning for joint vendor working sessions |
| 10 | 14/24 | same as item #9 |
| 11 | 11 | same as item #1 |
| 12 | 3 | same as item #4 |
| 13 | 4 | Cost of modifications charged to contractor |
| 14 | 2 | same as item #8 |

**Defining of Appropriate Quality Measures for Vendor Relations**

| Item # | Measures of Appendix B | Examples/Additional Information |
|---|---|---|
| 16 | 23/17 | Design of experiments to improve low yield processes |
| 17 | 10 | Inclusion of benchmarking to serve as baseline |
| 18 | 13/35 | - |

**Defining of Appropriate Quality Measures for Vendor Relations**

The following item #s with their associated measures were valid after the discussion:

| Item # | Measures of Appendix B |
|---|---|
| 1 | 11/25 |
| 2 | 1/18/19 |
| 3 | 14/28 |
| 4 | 3 |
| 6 | 7 |
| 8 | 2 |
| 9 | 9/14/24 |
| 13 | 4 |
| 15 | 5 |
| 16 | 17/23 |
| 17 | 10 |
| 18 | 13/35 |

Defining of Appropriate Quality Measures for Vendor Relations

The following table provides the voting results:

| Item # | Measures of Appendix B | Score J/R/Total | Ranking |
|---|---|---|---|
| 1 | 11/25 | 2/4/6 | 2 |
| 2 | 1/18/19 | 5/5/10 | 1 |
| 3 | 14/28 | 0/3/3 | 4 |
| 4 | 3 | 1/0/1 | 6 |
| 6 | 7 | 0/0/0 | |
| 8 | 2 | 0/0/0 | |
| 9 | 9/14/24 | 0/2/2 | 5 |
| 13 | 4 | 3/0/3 | 4 |
| 15 | 5 | 0/0/0 | |
| 16 | 17/23 | 4/1/5 | 3 |
| 17 | 10 | 0/0/0 | |
| 18 | 13/35 | 0/0/0 | |

# APPENDIX D

## PROTOTYPE QUESTIONNAIRE

## FOR

## VENDOR/CONTRACTOR RELATIONS MODULE

## OF A

## QUALITY MANAGEMENT SYSTEM

IDENTIFYING INFORMATION
FOR
QUESTIONNAIRE

PART I. QUESTIONNAIRE INFORMATION

A. QUESTIONNAIRE SERIAL NO.:

B. QUESTIONNAIRE RESPONSE DATE:

PART II. VENDOR INFORMATION

A. NAME OF VENDOR CIRCULATING QUESTIONNAIRE:

B. VENDOR ADDRESS:

C. VENDOR TELEPHONE NO.:

D. VENDOR FAX NO.:

PART III. RESPONDENT INFORMATION

A. NAME OF RESPONDENT:

B. NAME OF RESPONDENT'S ORGANIZATION:

C. DEPARTMENT WITHIN RESPONDENT'S ORGANIZATION:

D. RESPONDENT'S ADDRESS:

E. RESPONDENT'S TITLE:

F. RESPONDENT'S TELEPHONE NO.:

G. RESPONDENT'S FAX NO.:

MEASURES OF INTEREST[10]

PART I
1. Contracted product/service specifications
18. Quality management requirements in the procurement process
19. Identifying and communicating buyer requirements to the contractor

| | SD | D | N | A | SA |
|---|---|---|---|---|---|
| a. The contractor is flexible in negotiating product specifications with the buyer. | 1 | 2 | 3 | 4 | 5 |
| b. The contractor supplies the requested quantities of product on schedule. | 1 | 2 | 3 | 4 | 5 |
| | SD | D | N | A | NA |
| c. The contractor adheres to the required product specifications. | 1 | 2 | 3 | 4 | 5 |
| d. The contractor is prompt in meeting customer service needs. | 1 | 2 | 3 | 4 | 5 |
| e. The contractor takes customer service needs seriously. | 1 | 2 | 3 | 4 | 5 |
| f. The contractor is willing to solve quality issues. | 1 | 2 | 3 | 4 | 5 |
| g. The contractor is available when needed to solve quality-related problems. | 1 | 2 | 3 | 4 | 5 |
| h. The supplier's price structure is lower than industry norms. | 1 | 2 | 3 | 4 | 5 |
| i. The percentage of products that fails to meet specifications is less than the industry average. | 1 | 2 | 3 | 4 | 5 |
| ---------- | | | | | |
| j. There is a clear definition of quality in | 1 | 2 | 3 | 4 | 5 |

[10] The measures in this questionnaire are organized in three ways. Measures judged by *Delta's* development team to be similar or alike are first grouped into different "Parts." Part I measures were determined by the pilot organization to be the most meaningful; measures in Parts II, III, IV, etc. follow in order of their relative importance for the organization.

Within each "Part," numbers of the measures correspond to the numbers originally assigned to them when they were first developed (in Chapter 4). "Instances" or specific examples of each measure follow the measures themselves and are denoted by consecutive lowercase alphabetical letters.

| | SD | D | N | A | NA |
|---|---|---|---|---|---|
| c. The contractor adheres to the required product specifications. | 1 | 2 | 3 | 4 | 5 |
| d. The contractor is prompt in meeting customer service needs. | 1 | 2 | 3 | 4 | 5 |
| e. The contractor takes customer service needs seriously. | 1 | 2 | 3 | 4 | 5 |
| f. The contractor is willing to solve quality issues. | 1 | 2 | 3 | 4 | 5 |
| g. The contractor is available when needed to solve quality-related problems. | 1 | 2 | 3 | 4 | 5 |
| h. The supplier's price structure is lower than industry norms. | 1 | 2 | 3 | 4 | 5 |
| i. The percentage of products that fails to meet specifications is less than the industry average. | 1 | 2 | 3 | 4 | 5 |
| --- | | | | | |
| j. There is a clear definition of quality in the procurement process. | 1 | 2 | 3 | 4 | 5 |
| k. Both buyer and seller agree to the same definitions of quality. | 1 | 2 | 3 | 4 | 5 |
| l. The procurement process is continually improving. | 1 | 2 | 3 | 4 | 5 |
| m. PATs exist to analyze and improve quality in the procurement process. | 1 | 2 | 3 | 4 | 5 |
| n. PATs include representation from the supplier and all affected departments within the buyer's organization. | 1 | 2 | 3 | 4 | 5 |
| o. Meetings are frequent between buyer and seller for the purpose of establishing clear communication channels and fostering understanding. | 1 | 2 | 3 | 4 | 5 |
| p. There is adequate participation from all affected departments and levels within the organization in the procurement process | 1 | 2 | 3 | 4 | 5 |
| q. The procurement process includes feedback from the end user on product quality and service. | 1 | 2 | 3 | 4 | 5 |
| r. Product/service quality benchmarks are used to monitor vendors. | 1 | 2 | 3 | 4 | 5 |
| s. Sufficient cost data are available to award contracts. | 1 | 2 | 3 | 4 | 5 |

| | SD | D | N | A | NA |
|---|---|---|---|---|---|
| t. The number of end users providing feedback about product quality is _____. | | | | | |
| u. The percent of end users satisfied with procured products/services is _____. | | | | | |
| --- | | | | | |
| v. The number of surveys conducted within the last calendar year to solicit suggestions regarding procured products and services is _____. | | | | | |
| w. The total number of end user complaints which has led to on-site repairs is _____. | | | | | |
| x. The procurement process solicits end user requirements to determine different product characteristics. | 1 | 2 | 3 | 4 | 5 |
| y. The complaint resolution process is timely. | 1 | 2 | 3 | 4 | 5 |

MEASURES OF INTEREST

PART II

11. Assessment scores of subcontractors' quality management capabilities
25. Regularity and consistency in evaluating contractors' process quality, product quality, and quality management capabilities

| | SD | D | N | A | SA |
|---|---|---|---|---|---|
| a. The organization frequently evaluates its contractors. | 1 | 2 | 3 | 4 | 5 |
| b. The procedures for assessing contractors are validated. | 1 | 2 | 3 | 4 | 5 |
| c. The organization assesses its contractors according to standards that are communicated to the contractors. | 1 | 2 | 3 | 4 | 5 |
| d. Assessment of contractors on quality issues is consistent with the objectives of the procurement process. | 1 | 2 | 3 | 4 | 5 |
| e. The budget allocation for assessment and audits are adequate to meet objectives. | 1 | 2 | 3 | 4 | 5 |
| f. The number of audits/evaluations/assessments of vendors per six-month period averages____ | | | | | |
| g. Assessment scores are used to initiate improvements in the quality management system of the contractors. | 1 | 2 | 3 | 4 | 5 |
| h. The contractors assessment scores are improving over time. | 1 | 2 | 3 | 4 | 5 |
| i. The percent improvement in contractors assessment scores per six-month period averages _____. | | | | | |

MEASURES OF INTEREST

PART III

17. Criteria employed to assess contractor's quality management capabilities
23. Experimental design for measurement of quality indices

| | SD | D | N | A | SA |
|---|---|---|---|---|---|
| a. Criteria employed to assess quality management capabilities are comprehensive, covering all aspects of the quality management system. | 1 | 2 | 3 | 4 | 5 |
| b. Criteria are well understood by the assessor. | 1 | 2 | 3 | 4 | 5 |
| c. Criteria are well understood by the assessee. | 1 | 2 | 3 | 4 | 5 |
| d. Contractors are involved in the validation of assessment criteria. | 1 | 2 | 3 | 4 | 5 |
| e. The criteria used strictly confirm with the quality management paradigm. | 1 | 2 | 3 | 4 | 5 |
| f. Contractors are involved in the validation of assessment criteria. | 1 | 2 | 3 | 4 | 5 |

g. The number of references consulted in developing assessment criteria is approximately

h. The average cost associated with the assessment of quality management capabilities of each contractror is $_____.

MEASURES OF INTEREST

PART IV

14/28. Effectiveness in assisting contractor in resolving technical problems, quality issues, and productivity issues

| | SD | D | N | A | SA |
|---|---|---|---|---|---|
| a. The average number of joint contractor-buyer quality-related meetings, seminars and working sessions held per year is_____. | | | | | |
| b. At joint meetings between contractor and buyer regarding issues of quality, all affected departments and organizational levels within both institutions are included. | 1 | 2 | 3 | 4 | 5 |
| c. The number of PATs at contractor sites that include buyer participation when solving quality and productivity issues is_____. | | | | | |
| d. The number of solutions to problems of quality and productivity that originate with the contractor and are offered by the buyer is_____. | | | | | |
| e. To maintain acceptable performance the contractor needs little monitoring. | 1 | 2 | 3 | 4 | 5 |
| f. The customer gives contractor timely feedback on quality issues. | 1 | 2 | 3 | 4 | 5 |
| g. The customer gives accurate feedback on quality issues. | 1 | 2 | 3 | 4 | 5 |
| h. The average dollar amount spent (per contractor) in assisting vendors in solving quality-related problems is $_____. | | | | | |
| i. The customer is willing to share its know-how with contractor. | 1 | 2 | 3 | 4 | 5 |

MEASURES OF INTEREST

PART V

4. Cost measures

| | SD | D | N | A | SA |
|---|---|---|---|---|---|
| a. The cost to measure contractor performance is low. | 1 | 2 | 3 | 4 | 5 |
| b. The cost to monitor contractor performance is reducing over time. | 1 | 2 | 3 | 4 | 5 |
| c. The number of dollars spent per year to monitor contractor performance is $_____. | | | | | |
| d. The number of dollars spent annually by buyer to improve contractor relations is $_____. | | | | | |
| e. The percent of total contract value spent on contractor relations (i.e., communication, problem-solving, sharing of know-how, etc.) is_____ %. | | | | | |
| f. The total number of dollars allocated for CBD preparation, source selection plan, RFP preparation, and proposal evaluation is $_____. | | | | | |
| g. The costs totaled in "f" (above) are low. | 1 | 2 | 3 | 4 | 5 |
| h. The total dollars spent by contractor to solve quality-related issues is $_____. | | | | | |
| i. The total dollars spent by buyer to solve quality-related issues originating with the contractor is $_____. | | | | | |
| j. Actual total contract costs are less than total budgeted costs. | 1 | 2 | 3 | 4 | 5 |
| k. The percent of actual costs versus budgeted costs is +_____% | | | | | |

Measures of Interest

PART VI

9) The frequency of audits/assessments used to evaluate the buyer/contractor relationship.
24) Guidelines to determine the effectiveness of vendor/contractor assessments that evaluate quality attitudes, values, beliefs, and culture.
30) Evaluations to determine contractor capability in terms of product quality and supply timeliness.

| | SD | D | N | A | SA |
|---|---|---|---|---|---|
| a) The assessment results of the contractor buyer relationship show an improvement over time. | 1 | 2 | 3 | 4 | 5 |
| i) In the last one years | 1 | 2 | 3 | 4 | 5 |
| ii) In the last five year | 1 | 2 | 3 | 4 | 5 |
| b) Contractor and buyer share same quality | 1 | 2 | 3 | 4 | 5 |
| i) beliefs. | 1 | 2 | 3 | 4 | 5 |
| 11) values | 1 | 2 | 3 | 4 | 5 |
| c) Contractor buyer relationship is one of mutual trust. | 1 | 2 | 3 | 4 | 5 |
| d) Assessments show that a friendly relationship exists between buyer and contractor | 1 | 2 | 3 | 4 | 5 |
| e) The frequency of audits of the contractors quality management system are adequate. | 1 | 2 | 3 | 4 | 5 |
| i) The frequency is _____ per year. | 1 | 2 | 3 | 4 | 5 |
| f) The assessment scores of the contractors quality management system are used to initiate improvements in the system. | 1 | 2 | 3 | 4 | 5 |
| g) The contractors completely cooperates with the assessment. | 1 | 2 | 3 | 4 | 5 |
| h) The assessment covers all aspects of the quality management system. | 1 | 2 | 3 | 4 | 5 |
| i) The buyer evaluates the capabilities of the contractor to ensure quality of: | 1 | 2 | 3 | 4 | 5 |
| i) equipment and machinery | 1 | 2 | 3 | 4 | 5 |
| ii) process capability and control | 1 | 2 | 3 | 4 | 5 |
| iii) production Materials | 1 | 2 | 3 | 4 | 5 |
| iv) training and education of relevant workers in the contractors organization | 1 | 2 | 3 | 4 | 5 |
| v) procurement | 1 | 2 | 3 | 4 | 5 |
| vi) support activities | 1 | 2 | 3 | 4 | 5 |
| vii) management system | 1 | 2 | 3 | 4 | 5 |

MEASURES OF INTEREST -

PART VII

3) Quality related issues
20/33) Procedures/methods for identifying and resolving quality issues.

| | SD | D | N | A | SA |
|---|---|---|---|---|---|
| a) The no of quality issues that arise between the buyer and the contractor per month regarding: | | | | | |
| i) Product quality _____. | | | | | |
| ii) Maintenance _____. | | | | | |
| iii) Customer service _____. | | | | | |
| iv) Quality management system _____. | | | | | |
| v) Manufacturing process quality _____. | | | | | |
| b) The no. of quality issues arising between the buyer and the contractor is lower than a predefined limit in: | 1 | 2 | 3 | 4 | 5 |
| i) Product quality | 1 | 2 | 3 | 4 | 5 |
| ii) Maintenance | 1 | 2 | 3 | 4 | 5 |
| iii) Customer service | 1 | 2 | 3 | 4 | 5 |
| iv) Quality management system | 1 | 2 | 3 | 4 | 5 |
| v) Manufacturing process quality | 1 | 2 | 3 | 4 | 5 |
| c) The frequency of quality issues arising is reducing over time. | 1 | 2 | 3 | 4 | 5 |
| d) The % of all quality issues that arise more than once _____. | | | | | |
| e) Quality issues do not repeat themselves. | 1 | 2 | 3 | 4 | 5 |
| f) Contractor is prompt to resolve quality issues. | 1 | 2 | 3 | 4 | 5 |
| g) Contractor resolves all quality issues to the satisfaction of the customer. | 1 | 2 | 3 | 4 | 5 |
| h) Contractor is prompt to resolve all quality issues. | 1 | 2 | 3 | 4 | 5 |
| i) Contractor resolves quality issues on his own initiatives. | 1 | 2 | 3 | 4 | 5 |
| j) Contractor is proactive to uncover any quality related issues. | 1 | 2 | 3 | 4 | 5 |
| k) Contractor is available on a short notice to: | | | | | |
| i) discuss quality issues | 1 | 2 | 3 | 4 | 5 |

| | SD | D | N | A | SA |
|---|---|---|---|---|---|
| ii) solve quality issues. | 1 | 2 | 3 | 4 | 5 |
| l) There are specific procedures to: | | | | | |
| i) report quality issues within the organization. | 1 | 2 | 3 | 4 | 5 |
| ii) report quality issues to the contractors | 1 | 2 | 3 | 4 | 5 |
| iii) resolve quality issues with the contractor. | 1 | 2 | 3 | 4 | 5 |

MEASURES OF INTEREST

Part vii

5) Measures of buyer/contractor involvement in the improvement of buyer/contractor relations.

26) Effectiveness of the organization to involve all affected departments and personnel in both organizations in the procurement process, for example:
accounting, operations management, purchasing, planning , engineering, production/ manufacturing, quality assurance.

| | SD | D | N | A | SA |
|---|---|---|---|---|---|
| a) The no. of initiatives that the organization takes per year to: | | | | | |
| i) determine weaknesses/problems in its working relationship with the contractor_____. | | | | | |
| ii) solve problems in the working relationship with the contractor _____. | | | | | |
| b) There is encouragement for the employees to participate in improving buyer contractor relations in: | | | | | |
| i) the buying organization | 1 | 2 | 3 | 4 | 5 |
| ii) the sellers organization | 1 | 2 | 3 | 4 | 5 |
| c) The no. of joint stakeholder PATS existing to improve buyer/contractor relations_____. | | | | | |
| d) The no: of joint stakeholder PATS existing are adequate to solve the upcomming problems in buyer/ contractor relations. | 1 | 2 | 3 | 4 | 5 |
| e) Total dollar amount allocated in programms by the two organizations to improve working relations (This includes communication, understanding of each others requirement etc) _____. | | | | | |
| i) This amount is adequate to accomplish the objectives | 1 | 2 | 3 | 4 | 5 |
| f) The no. of employees participating in programs and/or PATS to improve buyer/contractor relations in: | | | | | |
| i) contractors organization_____. | | | | | |
| ii) buyers organization_____. | | | | | |
| g) The employees participating in programs to improve buyer/contractor relations are from all levels of the organization. | 1 | 2 | 3 | 4 | 5 |
| h) The no. of suggestions per employee received per year to improve customer/contractor relations_____. | | | | | |
| i) The no. of suggestions received per year from employees to improve contractor/buyer organization that were implemented_____ | | | | | |

MEASURES OF INTEREST

Part viii

6) Authority and responsibility to solve quality issues.

| | SD | D | N | A | SA |
|---|---|---|---|---|---|
| a) The no. of employees given the authority to define and solve quality issues between contractor and buyer in: | | | | | |
| i) The buyer organization_____. | | | | | |
| ii) The contractors organization_____. | | | | | |
| b) The communications channels between the contractor and buyer are accessible for solving quality issues by all affected employees from: | | | | | |
| i) all levels | 1 | 2 | 3 | 4 | 5 |
| ii) all departments | 1 | 2 | 3 | 4 | 5 |

MEASURES OF INTEREST

Part ix

7) The relevant training of the employees that take part in improving buyer/contractor relations.
a) The % of the employees in the buyer organization participating in improving buyer/contractor relations that are trained in :

i) process improvement_____.

ii) quality management_____.

iii) quality assurance_____.

iv) team building_____.

v) quality assessment_____.

vi) strategic planning_____.

vii) operational planning_____.

b) The % of the employees in the contractors organization participating in improving buyer/contractor relations that are trained in :

i) process improvement_____.

ii) quality management_____.

iii) quality assurance_____.

iv) team building_____.

v) quality assessment_____.

vi) strategic planning_____.

vii) operational planning_____.

MEASURES OF INTEREST

Part x

8/27) Communication channels between the buyer and contractor organization.

| | SD | D | N | A | SA |
|---|---|---|---|---|---|
| a) The communication channels are well defined. | 1 | 2 | 3 | 4 | 5 |
| b) The no. of communication channels between the organizations to communicate quality issues is adequate. | 1 | 2 | 3 | 4 | 5 |
| c) The communication channels are accessible to employees at all levels to solve quality issues in: | | | | | |
| i) The contractor's organization | 1 | 2 | 3 | 4 | 5 |
| ii) The buyer's organization | 1 | 2 | 3 | 4 | 5 |

Part xi

10) Parameters of incoming material acceptance sampling plans.

| | SD | D | N | A | SA |
|---|---|---|---|---|---|
| a) All incoming material that need sampling have a sampling plan. | 1 | 2 | 3 | 4 | 5 |
| b) The sampling plan for incoming material is adhered to . | 1 | 2 | 3 | 4 | 5 |
| c) Guidelines to prepare contract specific sampling plans exist. | 1 | 2 | 3 | 4 | 5 |
| d) Employees doing sampling are well trained. | 1 | 2 | 3 | 4 | 5 |

MEASURES OF INTEREST

Part xii

12) Contractor certification
16) Procedures for contractor selection and certification
29) Procedures for contracting.

| | SD | D | N | A | SA |
|---|---|---|---|---|---|
| a) The contractors are certified for all aspects of the quality management system. | 1 | 2 | 3 | 4 | 5 |
| b) Inspectors qualified in quality management practices do the certification. | 1 | 2 | 3 | 4 | 5 |
| c) The contractor is knowledgable of the different aspects of the certification program: | | | | | |
| i) Certification criteria | 1 | 2 | 3 | 4 | 5 |
| ii) Certification procedure | 1 | 2 | 3 | 4 | 5 |
| iii) All other requirements | 1 | 2 | 3 | 4 | 5 |
| d) Contractor certification is standardized for all contractors in terms of: | | | | | |
| i) Certification criteria | 1 | 2 | 3 | 4 | 5 |
| ii) Certification procedure | 1 | 2 | 3 | 4 | 5 |
| iii) All other requirements | 1 | 2 | 3 | 4 | 5 |
| e) The frequency of contractor certification is_____. | | | | | |
| f) The frequency of contractor certification is reducing. This is due to the following: | 1 | 2 | 3 | 4 | 5 |
| i) The contractor is increasingly reliable in provding quality products. | 1 | 2 | 3 | 4 | 5 |
| ii) The contractor is highly evolved in the practices of quality management | 1 | 2 | 3 | 4 | 5 |
| iii) The contractor has an self-assessment program equivalent to the certification program. | 1 | 2 | 3 | 4 | 5 |
| iv) The contractor self- assesses his/her quality management system frequently. | 1 | 2 | 3 | 4 | 5 |
| v) The contractor is proactive in initiating improvements. | 1 | 2 | 3 | 4 | 5 |
| g) The maturity of the quality management system in the contrator organization is a factor in the contractor selection process. | 1 | 2 | 3 | 4 | 5 |

| | SD | D | N | A | SA |
|---|---|---|---|---|---|
| h) There are precise procedures in the contracting process. | 1 | 2 | 3 | 4 | 5 |
| i) The potential contractors are briefed of the contracting procedures. | 1 | 2 | 3 | 4 | 5 |

MEASURES OF INTEREST

Part xiii

13) Quality improvement rewards for contractors given by the buyer.
35) Motivation and encourgement for the contractor to imrove quality

| | SD | D | N | A | SA |
|---|---|---|---|---|---|
| a) Contractors are promptly rewarded for quality improvement. | 1 | 2 | 3 | 4 | 5 |
| b) Contractors are adequatly awarded. | 1 | 2 | 3 | 4 | 5 |
| c) Contractors are awarded as per a defined rating system. | 1 | 2 | 3 | 4 | 5 |
| d) Contractor understand the rating system | 1 | 2 | 3 | 4 | 5 |
| e) The contractor is agreeable to the rating system | 1 | 2 | 3 | 4 | 5 |
| f) Suggestions from the contractors regarding improving the rating system are considered. | 1 | 2 | 3 | 4 | 5 |
| g) The rewards reinforce the objective of improving: | | | | | |
| i) quality management system. | 1 | 2 | 3 | 4 | 5 |
| ii) product quality | 1 | 2 | 3 | 4 | 5 |
| iii) service quality | 1 | 2 | 3 | 4 | 5 |
| h) To improve quality the contractor receives adequate: | | | | | |
| i) incentives | 1 | 2 | 3 | 4 | 5 |
| ii) recognition | 1 | 2 | 3 | 4 | 5 |
| j) A incentive for the contractor to improve quality is: | | | | | |
| i) awarding long term contracts | 1 | 2 | 3 | 4 | 5 |
| ii) awarding larger contracts | 1 | 2 | 3 | 4 | 5 |

MEASURE OF INTEREST

Part xiv

15) Planning for vendor\contractor relations

| | SD | D | N | A | SA |
|---|---|---|---|---|---|
| a) The no. of short-term and long-term objectives proposed per planning cycle_____. | | | | | |
| b) The no. of short-term and long-term objectives met per planning cycle_____. | | | | | |
| c) The no. of employees of the following levels involved in the planning procss: | | | | | |
| i) Executive level_____. | | | | | |
| ii) operational staff_____. | | | | | |
| iii) middle management_____. | | | | | |
| d) The no. of person hours spent to plan contractor buyer relations_____. | | | | | |
| e) The plans are consistent with the organizational vision of quality management development. | 1 | 2 | 3 | 4 | 5 |

MEASURES OF INTEREST

Part xv

34) Information system for the contractors.

| | SD | D | N | A | SA |
|---|---|---|---|---|---|
| a) An information system exists in the buying organization for the contractors exists to provide information on: | | | | | |
| i) processes, tools and techniques that are useful to the contractor to fulfill a given contract. | 1 | 2 | 3 | 4 | 5 |
| ii) procedures, policies and regulations relevant to doing business with the buyer | 1 | 2 | 3 | 4 | 5 |
| iii) any other information that helps the contractor to provide quality products and sevices. | 1 | 2 | 3 | 4 | 5 |
| b) The information system is: | | | | | |
| i) easily accessible | 1 | 2 | 3 | 4 | 5 |
| ii) accurate | 1 | 2 | 3 | 4 | 5 |
| iii) extensive | 1 | 2 | 3 | 4 | 5 |
| iv) comprehensible | 1 | 2 | 3 | 4 | 5 |

MEASURES OF INTEREST

Part xvi

31/32) Controls and benchmarks of contractor performance

| | SD | D | N | A | SA |
|---|---|---|---|---|---|
| a) The buyer benchmarks supplier perforfmance against: | | | | | |
| i) its other suppliers | 1 | 2 | 3 | 4 | 5 |
| ii) national industry leaders | 1 | 2 | 3 | 4 | 5 |
| iii) international industry leaders. | 1 | 2 | 3 | 4 | 5 |
| b) The buyer and contractor jointly establish indicators to: | | | | | |
| i) determine quality problems | 1 | 2 | 3 | 4 | 5 |
| ii) track quality over time | 1 | 2 | 3 | 4 | 5 |
| iii) control quality | 1 | 2 | 3 | 4 | 5 |

MEASURE OF INTEREST

Part xvii

21/22) Inspection and testing of incoming products.

| | SD | D | N | A | SA |
|---|---|---|---|---|---|
| a) The buyer has defined procedures for: | | | | | |
| i) inspection incoming products | 1 | 2 | 3 | 4 | 5 |
| ii) testing of incoming products | 1 | 2 | 3 | 4 | 5 |
| b) The buyer documents the results of | | | | | |
| i) testing incoming materials | 1 | 2 | 3 | 4 | 5 |
| ii) inspecting incoming materials | 1 | 2 | 3 | 4 | 5 |

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EDUCATION

M.S., Industrial Engineering, 1994, Virginia Polytechnic Institute & State University (VPI & SU), Blacksburg, VA, GPA 3.7.

B.S., Mechanical Engineering, 1988, M.S. Ramaiah Institute of Technology, Bangalore, India.

WORK EXPERIENCE

Nov 93-Nov 94: Management Engineer, Georgetown University Hospital, Washington, DC
* Responsible for cost accounting system
* Conducted engineering management studies for various hospital departments

May 93 - Aug 93: Systems Analyst, Industrial Engineering Dept., VPI & SU, Falls Church, VA
* For NAVSEA-sponsored DOD Management Systems Project, developed quantitative & qualitative measures for monitoring the performance and improvement of a quality management system applicable in a service or manufacturing environment of the defense industry
* Graduate thesis based on this research

Jan 92 - Apr 93 : Mechanical Engineer, Tri-Dim Filter Corp., Louisa, VA
* Responsible for product development & evaluation of high-tech industrial air filters
* Collected and analyzed data for improved process control & process design at Tri-Dim's manufacturing facility
* Headed regional (east coast) sales & marketing as well as customer support services for specialized ceramic filters at a collaborating German company

Aug 90 - Dec 91: Project Assistant, Industrial Engineering Dept., VPI & SU, Falls Church, VA
* For NAVSEA-sponsored DOD Management Systems Project, developed criteria for assessing & monitoring the performance of a quality management system in the defense industry. Developed design criteria & guidelines for implementing such a system.
* Evaluated existing quality management systems of two defense contractors

Jan 91 - May 91: Graduate Assistant, Engineering Dept., VPI & SU, Falls Church, VA
* Teaching Assistant for "Statistics In Research"

Oct 88 - Aug 89: Management Trainee, Modi Rubber, Ltd., Modipuram, India
* Trained in marketing, production management & support functions, procurement & inventory control, and R&D management at one of India's 10 largest industrial houses

Summers, 83 - 87: Summer Intern, MMC Corporation, Meerut, India
(Also, part time, '81-'83)
* Co-managed family's iron foundry business employing 40 people
* Oversaw production functions and procurement of raw materials
* Involved in product marketing and business administration

SKILLS Languages
* Fluent in English, German, Hindi, and Urdu

Computers
* Working knowledge of Word Perfect 5.1, Lotus 123, SuperCalc, DBase, Harvard Graphics, and LINDO
* Programming skills in Fortran, AML/E, Ladder Logic, SLAM II
* Extensive work on IBM 3090 mainframe with CMS, MVS/XA operating systems; IBM-compatible PCs with DOS environment

PERSONAL

* Extensive travel in Europe, Asia, and the United States
* Lived & schooled in Germany, 1975 - 1980

PROFESSIONAL PAPERS

Triantis, K., Caroli, V., and Puri, R., "Report on Process and Strategic Based Quality Measurement Guidelines for Quality Management System Development of Hardware Electronic Manufacturing Facilities, VPI & SU, June, 1993.

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