TOOLS AND TECHNIQUES OF QUALITY MANAGEMENT: AN EMPIRICAL INVESTIGATION OF THEIR IMPACT ON PERFORMANCE

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ABSTRACT

The management of quality has received considerable attention in recent years. Several studies have documented various elements of quality management, in particular the role of senior management in quality improvement efforts and the requirements for effective quality programs. This study provides details of an investigation of quality management at an operational rather than a strategic level. Using a survey of senior quality personnel, data was collected on four aspects of quality; the management of quality, the tools used by companies to improve quality, how companies document efforts to improve quality, and what dimensions of quality companies measure. Regression analysis confirms suggestions in the literature that company performance is positively impacted by a culture in which quality is ingrained. Moreover, it identifies positive relationships between several widely used operational practices and company performance.

Key Words: Quality Management

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Introduction

In recent years, quality management has become a major component of the strategies of business organizations. Intense global competition has forced firms to examine how they manage quality as they seek to enhance their competitiveness (Symons and Jacobs 1995). Total Quality Management (TQM) is considered by manufacturing executives to be one of their top strategic issues (Malhotra et al., 1994). In the last decade alone, between seventy-five and eighty percent of large companies have adopted TQM programs (Hiam 1993). However, while quality management efforts at some companies have resulted in improved competitiveness (Hendricks and Singhal 1994), similar results in other organizations have remained elusive (Hiam 1993, Grant et al., 1994).

The failure of many TQM programs to yield the anticipated outcomes stems in part from uncertainty in how the programs should be implemented (Greene 1993). The literature on quality management, a comprehensive review of which is presented in Ahire et al., (1995), is replete with approaches to managing quality. However, much of the literature has been descriptive in nature (Flynn et al., 1995). The lack of well-defined linkages between practice and outcome has, as a consequence, resulted in companies using initiatives in a piecemeal manner or without understanding their impact (Schaffer and Thomson 1992, Cole 1993). Only recently have attempts been made to establish a theory of quality management or to empirically identify relationships between quality management practice and performance.

Saraph et al., (1989) proposed and empirically validated eight components of quality management practice derived from the writings of quality 'gurus' (Table 1). They also demonstrated that both actual quality management (defined as manager's perceptions of quality management practice in their business units) and ideal quality management (manager's beliefs

regarding what quality management in the business should be) are dependent on organizational quality context (Benson et al., 1991). Organizational context was defined as the business unit manager's quality environment and operationalized using measures including managerial knowledge, corporate commitment to quality, quality performance, and company size/type.

Insert Table 1

Anderson et al., (1994, 1995) made the first attempt to develop a theory of quality management. They identified six constructs underlying the Deming philosophy of quality management and causal relationships between the constructs and performance, measured by customer satisfaction. Customer satisfaction was operationalized by management perceptions of their company's customer relations, product conformance, plant quality performance, and customer satisfaction, relative to those of industry competitors. Flynn et al., (1995) made a distinction between 'Core Quality Management Practices' (process flow management, product design process, statistical control/feedback) and 'Quality Management Infrastructure Practices' (customer relationship, supplier relationship, work attitudes, workforce management, top management support). These eight constructs were derived from practitioner and empirical studies of actual quality practice in the U.S. and Japan. The study identified relationships between the constructs and measures of performance similar to those in Anderson et al., (1995).

Ahire et. al (1996) identified eleven quality management constructs derived from the literature on quality management. They showed that all eleven constructs correlated positively with product quality. Product quality was measured by company representatives' assessments of their company's product performance, reliability, conformance, and durability relative to that of industry standards, as well as the percent of items that resulted in scrap or required rework. Black

and Porter (1996) used the Malcolm Baldrige National Quality Award (MBNQA) framework to examine quality management practices. In addition, they identified several quality management practices not embodied in the MBNQA. Their analysis yielded ten 'critical factors of TQM' though they did not attempt to identify relationships between the constructs and performance.

While these studies have articulated frameworks for quality practice, their focus has been on quality management at a strategic level, identifying requisite elements of quality management programs and the role of management in promoting quality improvement efforts. Less attention was paid to operational level details of how to implement and measure quality improvement, and how this impacts performance. With the exception of a survey of quality control techniques used by U.S. firms (Modaress and Ansari, 1989), there is little evidence in the literature of studies addressing such operational level issues as the implementation of quality control, the documentation of quality improvement efforts, or the measurement of quality performance. More importantly, no attempt has been made to integrate the strategic and operational dimensions of quality management in a common framework. The aim of this study is to develop such a framework. Three objectives underlie the study. The first is to evaluate how quality is managed within organizations. This will allow the results of the study to be compared to existing frameworks for quality management. The second objective is to identify how companies are implementing efforts to improve quality through the use of tools, documentation, and measurement. The third objective is to determine how the four elements of a quality management strategy, management practice, use of operational tools, documentation, and measurement, contribute to improving an organization's performance and competitiveness.

Research Constructs

Quality management practices are defined to be practices that reflect management's strategic orientation towards quality, a desire to formalize a company's commitment to quality, or the existence of an infrastructure for quality management. To operationalize this facet of quality, thirty-eight practices were identified (Appendix I, Part I). These include management's commitment to quality in policy development, how management's commitment is communicated throughout the organization, and how information on quality is collected, communicated, and used within the organization. Many of these items are similar to those used in prior studies.

Thirty-nine quality tools were identified (Appendix I, Part II). These include statistical tools such as control charts, acceptance sampling, and design of experiments, descriptive tools including histograms, Fishbone charts and Pareto charts, testing procedures such as durability and equipment testing, and the use of programs such as employee suggestion programs and supplier certification programs. To examine the extent to which companies document quality practices and performance, twenty-nine areas for documentation were identified (Appendix I, Part III). These include procedures for operating practices, inspection, testing and measurement, documentation of company as well as supplier performance regarding quality, and record keeping in areas such as product and process quality. Twelve dimensions used to measure quality were identified. These reflect different aspects of quality including delivery performance, customer satisfaction, and the cost of achieving quality (Appendix I, Part IV).

It is not uncommon to observe different quality practices being used at strategic business units within the same organization. Moreover, quality performance can vary significantly between business units in the same organization (Benson et. al, 1991). For these reasons, it was deemed appropriate to measure performance at the strategic business unit level. Five measures

were used to evaluate performance: market share, return on assets, customer service levels, product quality, and overall competitiveness. These measures, which reflect both financial performance and measures of a company's ability to meet market needs, provide a broader basis for examining the impact of quality management on performance than provided in past studies.

Survey Methodology

A survey instrument was designed based on the constructs described earlier. Respondents were asked to indicate, using a seven point Likert scale, the extent to which they used the quality management and documentation practices of interest (1 = very low use, 7 = very high use). For questions regarding quality tools, respondents were asked to indicate on a four point scale whether they used each tool (1 = tool is not used), and if so, whether the tools were used on a limited (2), moderate (3), or extensive basis (4). Respondents were also asked whether or not they measured each of the dimensions of quality. To elicit information on performance, respondents were asked to indicate, using a seven point Likert scale, their company's performance relative to that of major industry competitors (1 = performance well below that of major competitors, 7 = performance that is well above that of competitors).

Several steps were taken throughout the study, and in particular while developing the survey instrument, to minimize the impact of biases inherent in conducting survey research. To reduce common respondent bias, the bias associated with common responses regardless of question, the survey instrument was developed in a way that did not require respondents to answer all questions. The survey instrument was also pre-tested by quality managers or directors of ten firms in the United States and Europe. Of particular concern was the risk of social

desirability bias since some responses were based on respondent perceptions. Where necessary, questions were re-worded to improve validity and clarity.

The revised survey instrument was sent to 1,469 quality directors and vice presidents identified from an American Society for Quality membership list. Firms represented by these individuals came from a cross section of industries including the automotive, chemical, computer, defense, electronics, pharmaceutical, semiconductor, and telecommunications industries. Two mailings and one follow-up reminder yielded a response rate of 21.3% (313 returned surveys).

To test for non-response bias, returned surveys were split into two groups based on whether they were received early (227 surveys) or late (76 surveys). Responses contained in late returned surveys were considered to be representative of non-respondents (Armstrong and Overton 1977, Lambert and Harrington 1990). The tests were carried out on mean responses between the two groups to ten, randomly selected questions. These yielded no statistically significant differences suggesting that non-response bias was not present. To test for common method bias, a subset of seventy five responding firms was selected. Several financial indicators for these firms were compared to four measures of the firms' financial performance obtained from the Dunn and Bradstreet database for the same time period during which data was collected. Statistically significant correlations suggest that common method bias was not present.

The responding companies varied in size, employing between 12 and 256,000 employees. Twenty-two percent of the companies employed fewer than one hundred employees while nine percent employed more than 8,000 employees. Annual sales (1993) of the companies ranged from $ 1 million to $ 65 billion and were concentrated in the United States and Canada (82%). Twenty-four percent of the companies were ISO 9000 certified.

Statistical Analysis

Reliability Analysis

The reliability of the Quality Management, Quality Tools, and Documentation scales was evaluated using Cronbach's ∀ (Cronbach 1951). The reliability of the Measurement scale cannot be evaluated in this way since responses to questions are of a yes/no nature. For each scale, a value of ∀ > 0.70 was obtained (Table 2) suggesting the scales were reliable (Nunnally, 1988).

Insert Table 2

Preliminary Findings

Mean responses for the thirty six quality management practices ranged from 2.84 to 5.09 with a median of 4.42. This suggests that a wide variety of practices are used by the companies surveyed. Bonferroni multiple comparisons were inconclusive (Table 3). However, practices receiving the highest mean scores include developing procedures for monitoring performance, emphasizing health and safety in quality policy, and coordination between quality and other departments. The use of training in advanced statistical techniques stood alone as the least commonly used practice. Other practices receiving low mean scores include developing procedures to monitor the performance of competitors, using benchmark data to improve quality practices, and including customer attributes in product design using quality function deployment. It is interesting to observe that while companies are active in monitoring their own performance and customer quality requirements, they are less likely to monitor the performance of competitors or include customers in the product design process. This suggests a willingness of companies to remain internally focused in their management of quality.

Insert Table 3

Mean responses to questions regarding quality tools ranged from 1.54 to 3.34 with a median of 2.55. Bonferroni multiple comparisons indicate that the most commonly used tools include equipment calibration testing, and material identification and control. The least frequently used tools include the use of Poka-yoke devices, and quality function deployment.

Insert Table 4

Mean responses to questions on documentation ranged from 3.27 to 5.78 with a median of 5.13. While documentation of records for final inspection and testing received the highest mean score, several other practices also received high scores. These include the documentation of equipment inspection, testing, and measurement, and the development of a comprehensive quality assurance manual for the business unit. Documentation of supplier cost control, supplier process capability, formal design and verification of process plans, and documentation of supplier contract review are the least prevalent areas for documentation. This further supports the assertion that companies are internally focused in their quality management efforts.

Insert Table 5

Data on measurement indicate that while companies are interested in measuring marketplace performance as part of their quality strategy, they are less inclined to measure the costs associated with quality. More than 80% of responding firms measure after sales customer complaints (86%), on time delivery to customers (85%), and customer rejection of products (83%), though only 42% measure customer retention rate. While 73% of firms measure scrap rates/costs, only 38% measure prevention and appraisal costs and 40% measure warranty costs.

Tracking quality related costs often requires the use of complex Activity Based Costing or Total Cost Systems which separate out specific cost items. Quality costs are more often reported as part of broader cost categories and not identified on an item by item basis, thus the apparent reluctance to measure them. The remaining performance measures are used by between 50 and 67% of firms.

Factor Analysis

Factor analysis was used to reduce the Quality Management Practices, Quality Tools, and Documentation scales to a smaller number of underlying factors. The Measurement scale, being based on binary responses, cannot be reduced using factor analysis. The Principal Components method was used to extract factors (eigen values > 1) and Varimax rotation was used to obtain a more interpretable factor matrix. The Bartlett Test of Sphericity and the Kaiser-Meyer-Olkin measure of sampling adequacy were used to validate the use of factor analysis.

Seven factors were obtained from the Quality Management Practices scale (Table 6). These reflect the orientation of management towards quality, the design of various quality systems, and the role of information in managing quality. The seven factors account for sixty five percent of total variation and mirror those obtained in previous studies (Table 1). The Quality Tools scale yielded six factors (Table 7). These reflect the use of tools for process control, design for quality, and quality improvement. The six factors account for fifty six percent of total variation. The Documentation scale yielded three factors that address the documentation of process management efforts, overall quality procedures, and supplier capability (Table 8). The three factors explain sixty four percent of total variation

Insert Table 6

Insert Table 7

Insert Table 8

Regression Analysis

For each of the performance measures, multiple linear regression was carried out using the sixteen factors described above and the ten categorical variables corresponding to the measures of quality (referred to as M_1 – M_{12}). The Durbin-Watson statistic and normal probability plots were used to verify that residuals were independent and normally distributed. With one exception, all regression models were significant ($\alpha = 0.10$, Table 9).

Insert Table 9

Discussion

Two factors relating to quality management practice, company orientation towards quality, and data collection, have a positive impact on three of the four performance measures for which the regression models were significant. Two others, those relating to information flow and social responsibility are significant in at least one model. The role and attitude of management in managing quality has been well documented (e.g., Ahire et al., 1996) thus it is no surprise that factor QM_1 appears in all but one of the significant models. However, it is interesting to note that the one performance measure not affected by the factor is return on assets, the only financial measure of performance. Similarly, it comes as no surprise that attempts to monitor quality performance through benchmarking against competitors' performance or by collecting pertinent information from customers, positively impacts performance. It is notable that product quality is not positively affected by this factor. This is consistent with the earlier observation that

companies appear to have an internal focus in their product design processes, not availing themselves of external inputs into the process. It is significant that both competitiveness and return on assets correlate positively with positive management attitudes towards social responsibility. This supports the assertion that an emphasis on short-term decision making oriented towards cost control and minimizing 'avoidable' capital expenditures may not be conducive to long term financial health and competitiveness. None of the management practices that address the design or support of production activity, i.e., factors QM_3, QM_5, and QM_7 have a significant impact on any of the performance measures. While this appears counter-intuitive, it suggests that developing an organizational culture driven by quality may supersede the need to design specific processes to support quality goals.

The only category of quality tools to positively impact performance is tools to analyze and control processes. This is consistent with evidence that suggests that maintaining the integrity of processes through prevention rather than by focusing on inspection is the key to improving quality (Greene 1993). Factor QT_2, which refers explicitly to the use of inspection and testing, is not significant in any of the models. However, using tools to analyze and control processes only has an impact on overall competitiveness. While it might have been anticipated that maintaining process integrity would result in improved product quality, this is not the case. This may be the result of companies having already achieved high levels of product quality. The use of certain tools, in particular descriptive tools such as fishbone charts and histograms correlates negatively with product quality. A possible explanation for this is that companies may be using these tools as their primary diagnostic tools and not as part of a broader package of tools for diagnosis and correction.

In three of the four significant regression models, one area of documentation, process management, correlates positively with performance. This further demonstrates not only the importance of managing processes as part of a broad-based quality strategy, but that documentation is a necessary part of this process. Documenting overall quality procedures and, surprisingly, supplier capability, does not have a significant bearing on any measure of performance. The latter observation again suggests that companies maintain an internal focus in managing quality.

Only three dimensions of measurement have a significant impact on performance. Of these, only warranty cost correlates positively with performance, and only when measuring overall competitiveness. Defect rates and overall cost of quality both correlate negatively with competitiveness, and defect rates also correlates negatively with return on assets. This may be the result of stronger companies no longer using these measures of quality because they either do not consider them to be useful, or because they do not feel they are relevant given their quality performance.

Summary

The importance of establishing an appropriate infrastructure to support quality improvement efforts has been extensively documented. This study highlights the fact that infrastructure development is not the only facet of quality management that can positively impact an organization's performance. More importantly, it illustrates the need to implement quality improvement efforts at an operational as well as at a strategic level. Companies use a variety of approaches to implement quality improvement at an operational level but not all such approaches are effective. Identifying those practices that are, allows management to channel resources into

quality improvement efforts effectively. Moreover, it allows companies to integrate individual practices into a broad based quality strategy rather than using them in the piecemeal manner cited as being the reason for many failed quality improvement efforts.

The importance of strategy development and assessment is consistent with recent changes in the framework for the Malcolm Baldrige National Quality Award (MBNQA). The evaluation criteria for the award are now referred to as 'Criteria for Performance Excellence' rather than the original 'Award Criteria'. The motivation for this change is to emphasize the relationship between quality practice and organizational performance. Of the 1,000 points allocated to various MBNQA criteria, 450 are now allocated to 'business results/performance'. The award therefore requires explicit evidence of the impact of quality plans and deployment on the competitive performance of the business. The linkages between quality plans and practices (approach and deployment in MBNQA terminology) and organizational performance identified by this study highlight the timeliness of the shift in emphasis of the MBNQA.

The results also highlight the fact that quality initiatives alone cannot improve profitability and market share. Firms must unceasingly pursue new markets, new technologies, and reduce costs. The belief that TQM programs automatically lead to improved financial performance, fails to recognize the increasing impact of shrinking markets and product life cycles, niche competitors, the lack of a well defined corporate strategy, and customer demands for price reductions. While TQM provides a framework within which to implement a well-conceived market strategy, it cannot undo the effects of a poorly conceived one. It is therefore imperative for quality managers to ensure that their quality implementation strategies, tactics, and measurements are correctly aligned with strategies in the areas of finance, operations, procurement, logistics, marketing, new product development, and sales.

References

Ahire, S.L., Landeros, R., and Golhar, D.Y. 1995. Total quality management: A literature review and an agenda for future research. *Production and Operations Management*, 4, 277-306.

Ahire, S.L., Golhar, D.Y., and Waller, M.A. 1996. Development and validation of TQM implementation constructs. *Decision Sciences*, 27, 23-56.

Anderson, J.C., Rungtusanatham, M., and Schroeder, R.G. 1994. A theory of quality management underlying the Deming method. *Academy of Management Review*, 19, 472-509.

Anderson, J.C., Rungtusanatham, M., Schroeder, R.G., and Devaraj, S. 1995. A path analytic model of a theory of quality management underlying the Deming management method: Preliminary empirical findings. *Decision Sciences*, 26, 637-658.

Armstrong, J. S., and Overton, T.S. 1977. Estimating non-response bias in mail surveys, *Journal of Marketing Research.* 14, 396-402.

Benson, P.G., Saraph, J.V., and Schroeder, R.G. 1991. The effects of organizational context on quality management: An empirical investigation. *Management Science*, 37, 1107-1124.

Black, S.A., and Porter, L.J. 1996. Identification of the critical factors of TQM. *Decision Sciences*, 27, 1-22.

Cole, R.E. 1993. Introduction to the special issue on total quality management. *California Management Review*, 35, 7-11.

Cronbach, L.J. 1951. Coefficient alpha and the internal structure of tests. *Psychometrika*, 16, 297-334.

Flynn, B.B., Schroeder, R.G., and Sakakibara, S. 1995. The impact of quality management practices on performance and competitive advantage. *Decision Sciences*, 26, 659-692.

Grant, R.M., Shani, R., and Krishnan, R. 1994. TQM's challenge to management theory and practice. *Sloan Management Review*, 35, 25-35.

Greene, R. 1993. *Global Quality: A Synthesis of the World's Best Management Models.* Milwaukee: American Society for Quality Control Press.

Hendricks, K.B., and Singhal, V.R. 1996. Quality awards and the market value of the firm: An empirical investigation. *Management Science*, 42, 415-436.

Hiam, A. 1993. *Does quality work? A review of relevant studies.* New York: The Conference Board.

Lambert, D. M., and Harrington, T.C. 1990. Measuring non-response bias in mail surveys. *Journal of Business Logistics*, 11, 5-25.

Malhotra, M.D., Steele, D.C., and Grover, V. 1994. Important strategic and tactical manufacturing issues in the 1990's. *Decision Sciences*, 25, 189-214.

Modaress, B., and Ansari, A. 1989. Quality Control Techniques in U.S. Firms: A Survey. *Production and Inventory Management Journal*, 30, 58-62.

Nunnally, J.C. 1988 *Psychometric theory.* Englewood Cliffs: McGraw Hill.

Saraph, J.V., Benson, P.G., and Schroeder, R.G. 1989. An instrument for measuring the critical factors of quality management. *Decision Sciences*, 20, 810-829.

Schaffer, R., and Thomson, H. 1992. Successful change programs begin with results. *Harvard Business Review*, 70, 80-89.

Symons, R. T., and Jacobs, R. A. 1995. A total quality management-based incentive system supporting total quality management implementation. *Production and Operations Management*, 4, 228-241.

APPENDIX I

I. Quality Management Practices

On a scale of 1 = very low to 7 = very high, indicate the most appropriate response regarding your firm's practice of the following:

1. Use of benchmark data to improve quality practices
2. Amount of coordination between quality department and other departments
3. Amount of training in quality awareness provided to hourly employees
4. Amount of training in quality awareness provided to managers and supervisors
5. Amount of training in basic statistical techniques such as histograms and control charts
6. Amount of training in advanced statistical techniques (design of experiments and regression)
7. Availability of quality data (internal to the organization)
8. Collection of after sales quality data
9. Coordination among appropriate departments in the product/service development process
10. Degree to which company environment is conducive to employee well-being and growth
11. Degree to which divisional top management is evaluated based on quality performance
12. Degree to which employees throughout organization are evaluated on quality results
13. Degree to which quality is emphasized in design process vis-à-vis cost or schedule objectives
14. Development of procedures for monitoring key indicators of competitor performance
15. Development of procedures for monitoring key indicators of customer satisfaction
16. Development of procedures for monitoring key indicators of plant/company performance
17. Effectiveness of the quality department in improving quality
18. Emphasis on quality instead of price in the supplier selection process
19. Extent to which cross functional teams are utilized
20. Extent to which employees can act on quality issues without approval from supervisors
21. Extent to which health and safety are emphasized by top management in our quality policy
22. Extent to which human resources management is affected by quality plans
23. Extent to which interfaces among different functional departments are formalized
24. Extent to which manufacturability is considered in the product design process
25. Extent to which manufacturing facility is used as showroom to demonstrate quality practices
26. Extent to which quality data is made visible (displayed at work stations)
27. Extent to which top management emphasizes environmental protection in our quality policy
28. Extent to which top management clearly communicates quality goals
29. Extent to which top management emphasizes quality through a well-defined quality policy
30. Extent to which top management focuses on customer quality requirements to establish strategy
31. Extent to which top management provides resources to carry out quality improvement
32. Inclusion of customer attributes in product design through Quality Function Deployment (QFD)
33. Management's efforts to recognize and reward quality improvements
34. Quality department plays an active role in providing specific training such as SPC
35. Quality department's emphasis on inspection as the primary means of achieving high quality
36. Responsiveness of employees in making suggestions regarding quality improvement
37. Timeliness of quality data (internal to the organization)
38. Visibility of the quality department

II. Quality Tools

On a scale of 1 = very low to 4 = very high, indicate your firm's implementation of each of the following quality tools and techniques:

1. Acceptance sampling
2. Continuous improvement programs
3. Component traceability control
4. Customer satisfaction surveys
5. Design of experiments (Taguchi techniques)
6. Design for manufacturability
7. Employee involvement in quality planning
8. Engineering drawing specification and control
9. Equipment calibration testing
10. Failure mode and effects analysis
11. Inspection by quality control inspectors
12. Fishbone charts
13. Gage repeatability and reproducibility studies
14. Histograms
15. Incoming inspection
16. Life and durability testing of products
17. Material identification and control
18. Pareto analysis and use of pareto diagrams
19. Poka-yoke-foolproof devices
20. Preventive maintenance
21. Problem reporting and resolution
22. Process capability studies
23. Process flow diagrams
24. Profit sharing with employees
25. Quality function deployment
26. Quality circles
27. Quality check-sheets
28. Record retention and internal quality audits
29. Regression analysis
30. Rework is performed in separate rework station
31. Statistical process control
32. Employee suggestion program
33. Supplier certification/qualification
34. Total quality management program
35. Uniform production workload
36. Workers perform final inspection
37. Workers perform in process inspection
38. Worker responsible for defect performs rework
39. Zero defects program

III. Documentation

On a scale of 1 = very low to 7 = very high, indicate the degree of formalization and written documentation your firm has developed in each of the following areas:

1. Development of comprehensive quality assurance manual for your business unit
2. Development of comprehensive quality manual for operating procedures in all areas
3. Development of comprehensive written quality policy for the company/business unit
4. Documentation of equipment inspection, testing, and measurement
5. Documentation of internal process control techniques/procedures
6. Documentation of product costing
7. Documentation of product safety and liability
8. Documentation of quality vis-à-vis customer expectations

9. Documentation of supplier assessment and selection
10. Documentation of supplier contract review
11. Documentation of supplier cost control
12. Documentation of supplier process capability
13. Formal design and verification of process plans
14. Formal planning for product design and development
15. Formalized documentation of quality training efforts
16. Formalized evaluation of market readiness control
17. Materials handling documentation (storage, packaging, and delivery) for all stages of production
18. Procedures for corrective action of non-conforming material in all stages of production
19. Process capability studies
20. Records for final inspection and testing
21. Records for production equipment maintenance and control
22. Records for purchased material traceability and control
23. Records for receiving inspection and testing
24. Records for verification and control of process change
25. Records for verification and control of product quality
26. Retention of records related to internal audits and problem reporting and resolution
27. Written records documenting production control – all aspects
28. Written records for in-process inspection and testing
29. Written records for inspection, testing, and control of measurement equipment

IV. Measurement

Indicate whether your firm uses any of the following, frequently used quality measures

1. After sales customer complaints
2. Cost of quality
3. Customer rejection of products
4. Customer retention rate
5. Customer satisfaction
6. Defect rates/cost
7. Growth/decline in customer base
8. On time delivery to customers
9. Prevention and appraisal related costs
10. Rework rates
11. Scrap rates/cost
12. Warranty cost

V. Performance

On a scale of 1 = below average to 7 = above average, indicate the level of your firm's performance on each of the following dimensions compared to that of major industry competitors:

1. Market share
2. Return on total assets
3. Overall customer service levels
4. Overall product quality
5. Overall competitive position

Saraph et al., (1989)	Anderson et al., (1994)	Flynn et al., (1995)	Ahire et al., (1996)	Black and Porter (1996)
Role of management leadership and quality policy	Visionary leadership	Top management support	Top management commitment	Corporate quality culture
				Strategic quality management
	Customer satisfaction	Customer relationship	Customer focus	Customer satisfaction orientation
Supplier quality management		Supplier relationship	Supplier quality management	Supplier partnerships
			Supplier performance	
	Internal and external cooperation			External interface management
Employee relations	Employee fulfillment	Workforce management	Employee empowerment	People and customer management
Training			Employee training	
		Work attitudes	Employee involvement	Teamwork structures
Process management	Process management	Process flow management		Operational quality planning
Process control[1]	Continuous improvement	Statistical control/feedback	SPC usage	
	Learning		Benchmarking	
Role of the quality department				
Quality data and reporting			Internal quality information usage	Quality improvement measurement systems
				Communication of improvement information
Product service/design		Product design process	Design quality Management	

[1] Process control was not initially proposed as a component of quality management. Analysis however determined that it was a distinct construct separate from process management.

Table 1. Quality Management Constructs

Scale	∀	Notes
Quality Management	0.956	Items 35 and 38 correlated weakly with other items. When omitted, a value of ∀ = 0.961 was obtained. These items were omitted from subsequent analysis.
Quality Tools	0.899	Items 1, 4, 11, 15, 24, 26, 30, 32, 36, 38 correlated weakly with other items. When omitted, a value of ∀ = 0.908 was obtained. These items were omitted from subsequent analysis.
Documentation	0.956	Items 6, 7, 8, 14, 16, 19 correlated weakly with other items. When omitted, a value of ∀ = 0.957 was obtained. These items were omitted from subsequent analysis.

Table 2. Reliability Analysis

Scale Item	Mean
16. Development of procedures for monitoring key indicators of plant/company performance	5.09
21. Extent to which health and safety are emphasized by top management in our quality policy	5.05
2. Amount of coordination between quality department and other departments	5.03
30. Extent to which top management focuses on customer quality requirements to establish strategy	4.86
7. Availability of quality data (internal to the organization)	4.82
17. Effectiveness of the quality department in improving quality	4.72
4. Amount of training in quality awareness provided to managers and supervisors	4.70
24. Extent to which manufacturability is considered in the product design process	4.67
29. Extent to which top management emphasizes quality through a well-defined quality policy	4.67
31. Extent to which top management provides resources to carry out quality improvement	4.66
10. Degree to which company environment is conducive to employee well-being and growth	4.64
9. Coordination among appropriate departments in the product/service development process	4.54
19. Extent to which cross functional teams are utilized	4.54
37. Timeliness of quality data (internal to the organization)	4.53
20. Extent to which employees can act on quality issues without approval from supervisors	4.49
28. Extent to which top management clearly communicates quality goals	4.44
3. Amount of training in quality awareness provided to hourly employees	4.43
15. Development of procedures for monitoring key indicators of customer satisfaction	4.41
27. Extent to which top management emphasizes environmental protection in our quality policy	4.38
34. Quality department plays an active role in providing specific training such as SPC	4.37
25. Extent to which manufacturing facility is used as showroom to demonstrate quality practices	4.35
18. Emphasis on quality instead of price in the supplier selection process	4.34
26. Extent to which quality data is made visible (displayed at work stations)	4.31
36. Responsiveness of employees in making suggestions regarding quality improvement	4.26
23. Extent to which interfaces among different functional departments are formalized	4.18
13. Degree to which quality is emphasized in design process vis-à-vis cost or schedule objectives	4.12
33. Management's efforts to recognize and reward quality improvements	4.07
8. Collection of after sales quality data	4.01
12. Degree to which employees throughout organization are evaluated on quality results	3.99
11. Degree to which divisional top management is evaluated based on quality performance	3.92
22. Extent to which human resources management is affected by quality plans	3.90
5. Amount of training in basic statistical techniques such as histograms and control charts	3.77
32. Inclusion of customer attributes in product design through Quality Function Deployment (QFD)	3.55
1. Use of benchmark data to improve quality practices	3.53
14. Development of procedures for monitoring key indicators of competitor performance	3.50
6. Amount of training in advanced statistical techniques (design of experiments and regression)	2.84

Table 3. Bonferroni Multiple Comparisons: Quality Management Practices

Scale Item	Mean
9. Equipment calibration testing	3.34
17. Material identification and control	3.21
8. Engineering drawing specification and control	3.13
28. Record retention and internal quality audits	3.13
37. Workers perform in process inspection	3.12
21. Problem reporting and resolution	3.03
2. Continuous improvement programs	3.00
23. Process flow diagrams	2.78
3. Component traceability control	2.75
34. Total quality management program	2.75
33. Supplier certification/qualification	2.67
18. Pareto analysis and use of pareto diagrams	2.62
14. Histograms	2.57
20. Preventive maintenance	2.55
31. Statistical process control	2.55
27. Quality check-sheets	2.51
7. Employee involvement in quality planning	2.46
22. Process capability studies	2.31
6. Design for manufacturability	2.27
12. Fishbone charts	2.21
16. Life and durability testing of products	2.15
13. Gage repeatability and reproducibility studies	2.03
10. Failure mode and effects analysis	1.97
5. Design of experiments (Taguchi techniques)	1.78
39. Zero defects program	1.69
35. Uniform production workload	1.68
29. Regression analysis	1.66
25. Quality function deployment	1.60
19. Poka-yoke-foolproof devices	1.54

Table 4. Bonferroni Multiple Comparisons: Quality Tools

Scale Item	Mean
20. Records for final inspection and testing	5.78
4. Documentation of equipment inspection, testing, and measurement	5.56
1. Development of comprehensive quality assurance manual for your business unit	5.52
29. Written records for inspection, testing, and control of measurement equipment	5.47
28. Written records for in-process inspection and testing	5.42
25. Records for verification and control of product quality	5.40
23. Records for receiving inspection and testing	5.39
3. Development of comprehensive written quality policy for the company/business unit	5.27
26. Retention of records related to internal audits and problem reporting and resolution	5.27
18. Procedures for corrective action of non-conforming material in all stages of production	5.16
22. Records for purchased material traceability and control	5.14
2. Development of comprehensive quality manual for operating procedures in all areas	5.13
5. Documentation of internal process control techniques/procedures	5.07
15. Formalized documentation of quality training efforts	4.68
21. Records for production equipment maintenance and control	4.68
27. Written records documenting production control – all aspects	4.66
17. Materials handling documentation (storage, packaging, and delivery) for all stages of production	4.61
9. Documentation of supplier assessment and selection	4.60
24. Records for verification and control of process change	4.60
10. Documentation of supplier contract review	4.27
13. Formal design and verification of process plans	3.88
12. Documentation of supplier process capability	3.53
11. Documentation of supplier cost control	3.27

Table 5. Bonferroni Multiple Comparisons: Documentation

Factor	Scale Items	Factor Loading
QM_1: Company orientation towards quality	31. Extent to which top management provides resources to carry out quality improvement	0.695
	29. Extent to which top management emphasizes quality through a well-defined quality policy	0.686
	30. Extent to which top management focuses on customer quality requirements to establish strategy	0.684
	28. Extent to which top management clearly communicates quality goals	0.678
	33. Management's efforts to recognize and reward quality improvements	0.632
	36. Responsiveness of employees in making suggestions regarding quality improvement	0.602
	10. Degree to which company environment is conducive to employee well-being and growth	0.594
	12. Degree to which employees throughout organization are evaluated on quality results	0.593
	11. Degree to which divisional top management is evaluated based on quality performance	0.573
	18. Emphasis on quality instead of price in the supplier selection process	0.518
	13. Degree to which quality is emphasized in design process vis-à-vis cost or schedule objectives	0.430
QM_2: Data collection	14. Development of procedures for monitoring key indicators of competitor performance	0.751
	15. Development of procedures for monitoring key indicators of customer satisfaction	0.638
	1. Use of benchmark data to improve quality practices	0.578
	8. Collection of after sales quality data	0.521
QM_3: Training	5. Amount of training in basic statistical techniques such as histograms and control charts	0.742
	3. Amount of training in quality awareness provided to hourly employees	0.688
	4. Amount of training in quality awareness provided to managers and supervisors	0.647
	6. Amount of training in advanced statistical techniques (design of experiments and regression)	0.643
	34. Quality department plays an active role in providing specific training such as SPC	0.538
QM_4: Information flow	7. Availability of quality data (internal to the organization)	0.730
	37. Timeliness of quality data (internal to the organization)	0.657
	2. Amount of coordination between quality department and other departments	0.521
	17. Effectiveness of the quality department in improving quality	0.472
	16. Development of procedures for monitoring key indicators of plant/company performance	0.428
QM_5: Product and process design	24. Extent to which manufacturability is considered in the product design process	0.689
	25. Extent to which manufacturing facility is used as showroom to demonstrate quality practices	0.605
	32. Inclusion of customer attributes in product design through Quality Function Deployment (QFD)	0.535
	26. Extent to which quality data is made visible (displayed at work stations)	0.475
QM_6: Social responsibility	21. Extent to which health and safety are emphasized by top management in our quality policy	0.803
	27. Extent to which top management emphasizes environmental protection in our quality policy	0.757
	22. Extent to which human resources management is affected by quality plans	0.506
QM_7. Organization of work structures	19. Extent to which cross functional teams are utilized	0.649
	20. Extent to which employees can act on quality issues without approval from supervisors	0.522
	9. Coordination among appropriate departments in the product/service development process	0.437
	23. Extent to which interfaces among different functional departments are formalized	0.368

Table 6. Factor Analysis: Quality Management Practices

Factor	Scale Items	Factor Loading
QT_1: Process analysis/control tools and techniques	13. Gage repeatability and reproducibility studies	0.784
	22. Process capability studies	0.767
	19. Poka-yoke-foolproof devices	0.640
	31. Statistical process control	0.627
	10. Failure mode and effects analysis	0.564
	5. Design of experiments (Taguchi techniques)	0.482
QT_2: Inspection and testing	17. Material identification and control	0.775
	28. Record retention and internal quality audits	0.772
	9. Equipment calibration testing	0.639
	3. Component traceability control	0.632
	20. Preventive maintenance	0.447
	33. Supplier certification/qualification	0.376
	21. Problem reporting and resolution	0.376
QT_3: Descriptive tools	18. Pareto analysis and use of pareto diagrams	0.716
	14. Histograms	0.713
	12. Fishbone charts	0.660
	23. Process flow diagrams	0.538
QT_4: Quality improvement programs	34. Total quality management program	0.779
	2. Continuous improvement programs	0.751
	7. Employee involvement in quality planning	0.615
	25. Quality function deployment	0.376
QT_5: Product quality	8. Engineering drawing specification and control	0.634
	37. Workers perform in process inspection	0.555
	16. Life and durability testing of products	0.524
	27. Quality check-sheets	0.522
	6. Design for manufacturability	0.514
QT_6: Other tools/techniques	29. Regression analysis	0.675
	39. Zero defects program	0.443
	35. Uniform production workload	0.370

Table 7. Factor Analysis: Quality Tools

Factor	Scale Items	Factor Loading
D_1: Process management	20. Records for final inspection and testing	0.792
	25. Records for verification and control of product quality	0.772
	28. Written records for in-process inspection and testing	0.703
	22. Records for purchased material traceability and control	0.684
	23. Records for receiving inspection and testing	0.654
	29. Written records for inspection, testing, and control of measurement equipment	0.641
	21. Records for production equipment maintenance and control	0.619
	18. Procedures for corrective action of non-conforming material in all stages of production	0.556
	24. Records for verification and control of process change	0.543
	27. Written records documenting production control – all aspects	0.518
	17. Materials handling documentation (storage, packaging, and delivery	0.486
D_2: Overall quality procedures	1. Development of comprehensive quality assurance manual for your business unit	0.812
	2. Development of comprehensive quality manual for operating procedures in all areas	0.726
	3. Development of comprehensive written quality policy for the company/business unit	0.685
	5. Documentation of internal process control techniques/procedures	0.645
	4. Documentation of equipment inspection, testing, and measurement	0.622
	26. Retention of records related to internal audits and problem reporting and resolution	0.591
	15. Formalized documentation of quality training efforts	0.436
D_3: Supplier capability	11. Documentation of supplier cost control	0.805
	12. Documentation of supplier process capability	0.796
	10. Documentation of supplier contract review	0.691
	13. Formal design and verification of process plans	0.666
	9. Documentation of supplier assessment and selection	0.609

Table 8. Factor Analysis: Documentation

Regression Model	R^2
Market Share: Not significant	
Return on Assets = $4.838 + 0.293\ QM_2 + 0.192\ QM_4 + 0.167\ QM_6 – 0.356\ M_6$	0.20
Customer Service = $5.375 + 0.148\ QM_1 + 0.158\ QM_2 + 0.239\ D_1$	0.25
Product Quality = $5.493 + 0.127\ QM_1 – 0.145\ QT_3 – 0.117\ QT_6 + 0.174\ D_1$	0.25
Competitiveness = $5.167 + 0.207\ QM_1 + 0.254\ QM_2 + 0.135\ QM_6 + 0.186\ QT_1 + 0.197\ D_1 – 0.333\ M_2 + 0.463\ M_{12}$	0.27

Table 9. Regression Analysis