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**Quality Management in the R&D Departments
of
Quality Award Winning Manufacturing Organizations**

by

Todd A. Boyle, B.I.S.

A thesis submitted to
the Faculty of Graduate Studies and Research
in partial fulfillment of
the requirements for the degree of

Master of Management Studies

School of Business
Carleton University
Ottawa, Ontario
September 3, 1999

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A handwritten signature in cursive script, appearing to read "K. Kumar", written over a horizontal line.

Chair

A handwritten signature in cursive script, appearing to read "School of Business", written over a horizontal line.

Department

A handwritten signature in cursive script, appearing to read "K. Kumar", written over a horizontal line.

Thesis Supervisor

CARLETON UNIVERSITY

Date *Sept 17, 1999*

ABSTRACT

This research examines quality in the R&D departments of manufacturing-based organizations that have won the Canada Awards for Business Excellence, Malcolm Baldrige National Quality Award, or the Shingo Prize for Excellence in Manufacturing.

The specific issues that are analyzed include: the management practices R&D managers perceive to be important for quality management in R&D, the usage and appropriateness of specific quality management tools in R&D, and biases that R&D managers may have towards applying quality practices to research activities.

In addition to these issues, a model is developed to explain how specific quality management practices can lead to a quality culture and ultimately quality management in R&D.

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DEDICATION

To Becky and family, for their kindness

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CHAPTER 1

INTRODUCTION

North American organizations have finally realized the importance of quality in the production of goods and services (Evans & Lindsay 1999). However, the idea of producing quality goods and services is not new. Quality ideas have evolved from simple mid-eighteen century quality assurance techniques to the modern management philosophies of Deming, Juran, and Crosby (Evans & Lindsay 1999). As this evolution has occurred, the organizational benefits of implementing quality have also evolved to a point where it has begun to lose its competitiveness appeal and is quickly becoming a major factor required for organizational survival (Fisher et al. 1992). Even with this additional pressure for organizations to produce quality goods and services, quality management (QM) of research and development (R&D) activities is still not being adequately addressed by organizations operating in the wake of the quality revolution (Meyer et al. 1997).

This research examines the QM practices and perceptions that exist in the R&D departments of manufacturing organizations that have won the Canada Awards for Business Excellence, Malcolm Baldrige National Quality Award, or the Shingo Prize for Excellence in Manufacturing. The research determines those QM practices that R&D managers perceive to be critical for the successful implementation of a QM program into the R&D departments of manufacturing companies. QM tools are then presented to R&D managers to determine the extent of usage and appropriateness of such tools in the R&D environment. Finally, this research determines if biases towards QM in R&D are found amongst R&D managers.

CHAPTER 2

LITERATURE REVIEW

The operational definition of research and development for this research is taken from the Organization of Economic Co-operation and Development, and is formally defined as the “creative work undertaken on a systematic basis to increase the stock of scientific and technical knowledge and to use this stock of knowledge to devise new applications”. Research and development can be categorized into three broad groups depending upon the research activities being conducted, specifically research and development for basic research, research and development for applied research, and research and development for innovation (Jain & Triandis 1989).

Research and development for basic research includes producing “significant advances across the broad front of understanding of natural and social phenomena” (Jain & Triandis 1989). Research and development for applied research involves “fostering inventive activity to produce technological advances” (Jain & Triandis 1989). Finally, research and development for innovation combines “understanding and invention in the form of socially useful and affordable products and processes” (Jain & Triandis 1989).

2.1 - Types of R&D Organizations

Jain and Triandis (1989) suggest that organizations with an R&D component will fall into one of three broad categories, identified as mission oriented research organizations, scientific institutional organizations, and academic research organizations. Mission oriented research organizations include companies where R&D activities are

defined on the basis of business goals (Jain & Triandis 1989). Research activities include supporting other functional areas of the organization in addition to conducting applied and basic research. Organizations with a primary mission defined on the basis of scientific goals and research interest are categorized as scientific institutional organizations (Jain & Triandis 1989). Academic research organizations are similar to scientific institutional organizations, but are smaller in size with research goals and activities based upon academic department, professor, and student research interests.

This research addresses mission oriented research organizations, specifically the R&D departments of manufacturing organizations that are focused on applied research and development activities.

2.2 - Quality Management in Organizations

As previously mentioned, concepts of quality have evolved over the last 250 years. As they did, it is not surprising that the definition of quality has also changed to a point where no single universally accepted definition exists. Quality is defined on the basis of different criteria in the organization, identified as follows:

Table 1
Criteria for Defining Quality

<i>Criteria</i>	<i>Description</i>
Judgmental	Above and beyond ordinary limits.
Product-Based	Differences in quantity of some attribute.
User-Based	Determined by consumers' wants.
Value-Based	Relationship of satisfaction at a comparable price.
Manufacturing	Conformance to specifications.

(Evans & Lindsay 1999)

These different criteria have caused difficulty in determining a universally accepted definition of quality. None of the above definitions alone capture the true meaning of quality. Therefore, an organization that focuses on only a single criterion may not produce quality goods and services. The ISO-8402 (1986) formal definition of quality attempts to capture all the above criteria and will therefore form the operational definition for this research. This source states quality as “the totality of features and characteristics of a product or service that bears on its ability to satisfy stated or implied needs”.

The ISO definition of QM is stated in the ISO/CD 8402-1 “Quality Concepts and Terminology - Part 1: Generic Terms and Definitions”. This definition of quality management is:

A management approach of an organization, centered on quality, based on the participation of all its members and aimed at long-term profitability through customer satisfaction, including benefits to the members of the organization and to society.

This definition does not take into account i) exceeding the customer’s expectations, ii) the strategic importance of quality management and iii) the view that quality management is a continual effort by all members in the entire organization. The operational definition of quality management for this research has been adapted from Evans & Lindsay (1996) summarization of total quality. This definition considers the above three points not addressed in the ISO/CD 8402-1 “Quality Concepts and Terminology - Part 1: Generic Terms and Definitions”, and is defined as:

A management system of an organization aimed at a continual increase in customer satisfaction and expectations at continually lower costs. Quality management is a total system approach and an integral part of high-level strategy; it works horizontally across functions and departments, involves all employees, top to bottom, and extends backward and forward to include the supply chain and the customer chain. Quality management stresses learning and adaptation to continual change as keys to organizational success.

2.3 - Quality Management Philosophies

Three individuals have played a critical role in organizations realizing the importance of quality. The works of Deming, Juran, and Crosby have been so important that their ideas on quality are considered philosophies (Evans & Lindsay 1999). Deming's view of quality suggests that causal and random variation in the production process are the main factors leading to poor quality. To increase quality, process variation needs to be identified and removed. Deming suggests that to eliminate process variation, organizations should adopt a continuous cycle of product design, manufacturing, test, sales, market surveys, redesign. This cycle will cause the "Deming Chain Reaction", allowing for quality improvements to occur within the organization. These quality improvements will decrease costs, improve productivity, and increase market share.

Deming's philosophy on QM is encapsulated in Deming's 14 Points (Exhibit 1). However, Deming's 14 Points have caused some confusion in operations management, since Deming did not provide any scientific basis for these points. To alleviate this confusion, Deming combined his 14 points into a new system called the "System for Profound Knowledge". This system is comprised of four interrelated components, including an appreciation for the system, an understanding of variation, theory of

knowledge, and psychology.

Juran suggests that North American organizations need to focus on three main areas of quality. These three areas form the basis for Juran's Quality Trilogy and is described in Table 2.

Table 2

Juran's Quality Trilogy

<i>Quality Area</i>	<i>Description</i>
Quality Planning	Preparing to meet quality goals.
Quality Control	Meeting quality goals during operations.
Quality Improvement	Breaking through to unprecedented performance levels.

(Evans & Lindsay 1999)

The main focus of Juran's philosophy involves identifying customers, determining their needs, constantly developing products which satisfy these needs, and linking quality plans to the organization's strategic plan. These concepts help emphasize that QM must be a continual process.

Crosby's quality philosophy is presented in the "Absolutes of Quality Management" (Exhibit 2) and "Basic Elements of Improvement" (Exhibit 3). Most of Crosby's ideas suggest that the line-worker should strive for perfection. This idea differs greatly from the philosophies developed by both Deming and Juran. For example, Deming and Juran emphasize that it is useless for the line-worker to be perfect, since a large portion of inefficiency is the result of poor process design, poor production design, and random process variation which are beyond the immediate control of the line-worker.

2.4 - Quality in Research and Development

A review of the current research literature reveals that there is no one common definition of quality in R&D. A number of researchers have attempted to define quality in an R&D context. Roberts (1991) defines quality in R&D as accomplishing the defined objective of the research in a manner that is correct, reproducible, and efficient in time and budget. Patino (1997) gives a similar definition of quality in R&D. He states that quality in R&D involves doing “it the right way the first time, learning from and improving it each time and getting the results the company needs”. The major weakness of these definitions is that both fail to address the needs of the R&D client. Wood & McCamey’s (1997) definition of quality in R&D address the specific involvement of the R&D client. They summarize quality in R&D as really knowing your customers, doing things right once you are sure you are working on the right things, concentrating on continually improving the system, enabling people by removing barriers and encouraging people to make their maximum contribution. Schumann et al. (1995) attempt to address the needs of the R&D client in their summarization of R&D quality. They state that the:

essence of quality in R&D, as in other fields, is a market focus. This requires that there be an understanding of who the customer is and what his or her values and expectations are, what the key technologies are and how they can be used to meet customers expectations. Who the competitors are and how they will respond to emerging customers needs.

The operational definition of quality in R&D for this research is a combination of Wood & McCamey (1997) and Schumann et al. (1995) summarization of quality in R&D and is stated as:

An understanding of who the R&D client is and what his or her values and expectations are, what the key technologies are and how they can be used to meet R&D clients' expectations and the needs of the entire organization, and who the R&D competitors are and how they will respond to emerging R&D clients needs. This is achieved by doing things right once you are sure you are working on the right things, concentrating on continually improving the system, enabling people by removing barriers, and encouraging people to make their maximum contribution.

Francis (1992) captures the relationship between the R&D client and the organization.

Francis (1992) emphasizes that:

R&D must understand that it has a customer: the company. R&D exists to strengthen and advance the objectives of the company, which in turn generally are to serve the interests of its customers, investors, employees, and the communities wherein it operates.

This research is focused on the R&D departments of manufacturing organizations. The R&D client is therefore other functional areas within these manufacturing organizations.

2.5 - Canada Awards for Business Excellence

The Canada Awards for Business Excellence was established in 1984 by the Canadian Government to recognize businesses in all industry sectors for their achievements. The award is given for business achievement in eight different areas including, Entrepreneurship, Environment, Industrial design, Innovation, Invention, Marketing, Quality, and Small business. Only manufacturing-based winners in the quality and productivity categories are addressed by this research. Awards in these categories are given to organizations for their overall commitment to continuous quality improvement with an emphases placed on the "total involvement of the company, including all business functions and all employees, on the competitiveness of the product or services in the marketplace and on a high level of customer satisfaction" (Puri 1992). The evaluation

criteria for the award are the organization's quality improvement policy and plan, implementation policy and plan, results achieved, and future planning.

2.6 - Malcolm Baldrige National Quality Award

The Malcolm Baldrige National Quality Award came into existence in 1987 with the purpose of promoting awareness of quality excellence, recognizing quality achievements of US companies, and publicizing successful quality achievements. The Awards is only given to US companies specifically:

Any for-profit business or sub-unit headquartered in the United States or its territories, including U.S. sub-units of foreign companies may apply for the Award. Eligibility is intended to be as open as possible. For example, publicly or privately owned, domestic or foreign owned companies, joint ventures, corporations, sole proprietorships, and holding companies may apply. Not eligible are: local, state, and national government agencies; not-for-profit organizations; trade associations; and professional societies.

(National Quality Program 1999)

Each award application is evaluated by five members of a board of examiners, comprised of individuals from both academia and industry. The evaluation criteria is based upon criteria created through a public-private partnership. The board of examiners assigns a score to each applicant. High-scoring applicants are selected for site visits by a panel of judges. The judges then recommend award recipients to the United States Secretary of Commerce from among the sites visited. (National Quality Program 1999)

Each applicant is examined on seven areas specifically, leadership, information and analysis, strategic quality planning, human resource utilization, quality assurance of products and services, quality results, and customer satisfaction. The maximum number

of points an organization can obtain is 1000. Each category has a different allocation of possible points, demonstrating an emphasis on specific areas over others. The point distribution of the award is illustrated as follows:

Figure 1

Baldrige Award Point Distribution

1=leadership, 2=information & analysis, 3=strategic quality planning, 4=human resource utilization, 5=quality assurance of products and services, 6=quality results, 7=customer satisfaction.

The United States National Institute of Standards and Technology awards a maximum of two awards annually to each of the manufacturing companies or subsidiaries, service companies or sub-units, and small businesses categories. This research addresses award winners in the manufacturing companies & subsidiary category.

2.7 - Shingo Prize for Manufacturing Excellence

The Shingo Prize for Manufacturing Excellence was established in 1988 with the purpose of promoting North American organizations that excel in productivity, process improvement, quality enhancement, and customer satisfaction. Utah State University administers the award, in partnership with the American National Association of Manufacturers.

The award was named after Mr. Shigeo Shingo who has distinguished himself as a world expert on improving manufacturing processes. His achievements include creating many of the features of the just-in-time manufacturing methods, systems, and processes which make up the Toyota Production System (Shingo 1999).

The philosophy of the Shingo Prize is that world-class status may be achieved through focused improvements in core manufacturing processes, implementing lean, just-in-time philosophies and systems, eliminating waste, and achieving zero defects, while continuously improving products and costs. The prize is awarded annually to recognize North American manufacturing companies, divisions, and plants that demonstrate excellence in manufacturing leading to quality enhancement, productivity, improvement, and customer satisfaction. The award is based on a total of 1000 points, broken down as follows (Shingo 1999):

- **Total Quality and Productivity Management Culture & Infrastructure: 275 pts.**
 - Leading: 100
 - Empowering: 100
 - Partnering: 75
- **Manufacturing Strategy, Processes, and Systems: 425 pts.**
 - Manufacturing Vision and Strategy: 50
 - Manufacturing Process Integration: 125
 - Quality and Productivity Methods Integration: 125
 - Manufacturing and Business Integration: 125
- **Measured Quality and Productivity: 200 pts.**
 - Quality Enhancement: 100
 - Productivity Improvement: 100
- **Measured Customer Service: 100 pts.**
 - Customer Satisfaction: 100
- **Total Points: 1000 pts.**

The Shingo Prize for Excellence in Manufacturing has two categories i) large manufacturing companies, subsidiaries, plants and ii) small manufacturing companies. This research only address organizations that have won an award in the large manufacturing companies, subsidiaries, and plants category and are located in either Canada or the United States.

CHAPTER 3

A MODEL FOR IMPLEMENTING QUALITY MANAGEMENT

Puri (1992) suggests that there are various ways in which an organization can implement a QM program. Such methods include implementing a self-developed / self-directed QM system, adopting a formal QM model, or adopting approaches and methods suggested by Deming, Juran, and Crosby. Examples of self developed / self directed QM systems include Roberts (1991) Babcock & Wilcox case and case studies conducted by Szakonyi (1992). Formal QM models may include those models developed by national and international standard bodies. An example of a formal QM model is IS-9004. An example in the current research literature of a company adopting the approaches suggested by Deming, Juran, or Crosby is Keiser & Blake's (1996) case of Nalco Chemical Company. Regardless of the approach taken, Puri (1992) suggests that a QM system should have a quality philosophy and management responsibilities; quality policies, plans, systems, procedures, and processes; and quality tools and methodologies. To achieve the above components, Puri (1992) recommends a 7-step quality management model, diagrammed as follows:

Figure 2**Puri's 7-Step Quality Management Model**

To implement such a QM model, Puri (1992) suggests following a sequence of seven phases. Each phase and its related steps are identified below.

Phase One:

- Ensure management commitment.
- Foster management awareness/education/discussion.
- Establish a quality management steering committee.
- Appoint a quality management coordinator.
- Develop a quality management mission statement.

- Identify/document a quality policy.
- Develop quality objectives.
- Provide employee orientation/awareness/education.

Phase Two:

- Partner with suppliers and identify needs/requirements/mission.
- Partner with customers and identify needs/requirements/mission.
- Develop constancy/trust with suppliers and customers.

Phase Three:

- Identify all processes in the cycle.
- Create process improvement teams.
- Define process boundaries and requirements for each process.
- Define the current best process.
- Establish goals and priorities.
- Identify process control/improvement requirements.

Phase Four:

- Implement control/improvement projects.
- Establish measures of performance.
- Assess conformance to specified requirements.
- Take corrective/preventive action.

Phase Five:

- Identify improvement opportunities.
- Establish strategic initiatives.
- Continue process improvement.

Phase Six:

- Establish audit/evaluation procedures.
- Review each process and take corrective/preventive action.

Phase Seven:

- Repeat the entire cycle of activities, initiatives, and actions to continuously improve the system.

CHAPTER 4

THEORETICAL FRAMEWORK

This research addresses the appropriateness and extent of use of various QM practices and tools in the R&D departments of manufacturing organizations. R&D QM Tools (e.g. cause-effect diagrams and formal quality audits) are operational tools and techniques that are used to fulfill specific R&D requirements for quality. R&D QM practices (e.g. identifying and documenting existing R&D processes) are QM plans, policies, and processes for implementing QM into R&D departments.

The relationship between R&D QM practices and R&D QM tools can be illustrated by an organization's attempt to document their current R&D processes. Documenting current R&D processes can form part of the organization's plan to implement a QM program into their R&D department. There are a number of specific tools that can be used to identify and document the R&D processes that exist in the organization. Such QM tools include constructing tree diagrams, relation diagrams, or flow charts of R&D activities.

The QM tools suggested by Puri (1992), Miller (1994), and other researchers are presented to R&D managers to identify the extent of usage and perceived appropriateness of such tools in R&D departments. In addition to examining QM practices and tools, this research also examines if biases towards QM also exist among R&D managers.

4.1 - Quality Management Practices: Theoretical Framework

A review of the existing research literature fails to reveal a framework for the management practices required to implement a QM program into the R&D departments of manufacturing organizations. Puri's (1992) 7-step Quality Management Model does suggest practices for implementing a QM program, however it is not specific to R&D departments. Miller (1994) after interviewing research directors for fifty large international organizations, emphasizes that senior R&D managers use a variety of practices to achieve quality in R&D. These managers stress that quality is achieved through Strategic Analysis practices, Engineering of Processes, Research Evaluation practices, and Client Evaluation practices. Miller's (1994) QM practices will form the majority of the management practices for this research. These management practices are focused on R&D departments and have been statistically analyzed, but they do not specifically address R&D departments in *manufacturing* companies. Further it seems from the literature (Debackere et al. 1997, Keiser & Blake 1996, May & Pearson 1993, Patino 1997, Puri 1992, Szakonyi 1992), that Miller (1994), although addressing many of the important QM practices for R&D have missed some key QM practices that must be considered by R&D departments operating in a manufacturing environment.

Puri's (1992) model was not developed specifically for manufacturing. As a result it is possible that i) not all of Puri's (1992) management practices will apply to the R&D departments of manufacturing organizations and ii) there will be some overlap among the practices suggested by Miller (1994) and Puri (1992). However, since many of Puri's (1992) QM practices do apply to manufacturing, his 7-Step Quality Management Model will be used to identify QM practices that must be considered by R&D departments

operating in such an environment.

4.1.1 – Strategic Analysis Practices

Miller (1994) suggests that Strategic Analysis is required for QM in R&D. He argues that Strategic Analysis does not refer to senior management providing clear objectives and goals for the R&D department. Instead, he suggests that Strategic Analysis allow for R&D managers to become actively involved in the organization's strategic goals. The Strategic Analysis practices Miller (1994) found to be important among senior R&D managers include understanding corporate strategies (e.g. mission statement, strategic area that R&D must serve), competitive position & assessment (e.g. review of patents, publications, competitive position of the firms technology or product), surveillance of intellectual property, exploration groups (e.g. multi-functional groups used to identify possible future markets), review of strategic goals and R&D purpose, cost/benefit, risk analysis, and deliberations with senior managers.

Strategic Analysis starts with understanding the firm's mission and the strategic purpose of R&D. Competitive and technology assessments include such management practices as reviewing patents, publications, products, and the position of the firm's key technologies. Exploration groups, surveillance of intellectual property, risk analysis, cost benefit analysis, and reviews of strategic goals and R&D purpose are used to help identify future markets and opportunities for the R&D department. The final Strategic Analysis practice that Miller (1994) addresses is R&D managers and employees meeting with senior management. Miller (1994) argues that senior management does not have time to explore the possible future markets and business possibilities that may occur as a result of a specific emerging technology. To bring these possibilities to the attention of

senior management, Miller (1994) recommends that R&D managers and employees should meet with senior managers on either a monthly, quarterly, or yearly basis to identify R&D opportunities.

Puri (1992) also shows the importance of Strategic Analysis by suggesting that developing a mission statement and strategic initiatives are needed for the implementation of QM program into manufacturing. A review of the literature shows that other researchers also stress the importance of these practices to help achieve quality in R&D. Wood & McCamey (1994) demonstrate the importance of Strategic Analysis for achieving quality in R&D using the Health and Personal Care Technology Division of Procter and Gamble (HPCT) case. They suggest that focusing improvement efforts on the “strategic areas critical to the business” was a key factor to achieving quality in R&D at HPCT. Takahashi (1997) also addresses the need for Strategic Analysis by suggesting that managers must ensure that R&D projects match the corporate strategy and that “the most critical role for an R&D manager is to keep the R&D projects abreast of the corporate strategy at all times”.

4.1.2 – Engineering of Processes

Miller (1994) groups practices that focus on R&D processes under Engineering of Processes. Engineering of Processes:

outlines the product development steps to be carried out by multi-functional teams, including marketing, research, engineering, supplies, production and finance: design reviews are arranged to ensure compliance with specifications, standards, procedures, and regulations .

(Miller 1994).

The Engineering of Process practices Miller (1994) identified includes competitors benchmarking, modeling of processes, review of systems and processes, common

research databases and methodologies, documentation and reporting practices, personal transfer, and quality certification. Although there are no formal quality certification programs developed specifically for R&D, a number of quality certifications can be applied. Examples of quality certifications that can be applied to R&D include: ISO 9003 which focuses on assuring quality through testing, ISO 10011 which is a quality system auditing guide, and ISO 10013 which is a quality manual development guide (ISO Certification 1999).

Engineering of Processes requires the combined effort of the R&D department, customers, and suppliers and allows for the identification of opportunities, obstacles, and controversies regarding the proposed innovation or research. Engineering of Process involves participation of clients in defining requirements, allows for the identification of processes, and emphasizes work teams that “bring together upstream players and downstream players” (Miller 1994) such as production and procurement. Purdon (1994) also argues the importance of cross-functional groups by suggesting the development of Market Segment teams. Purdon (1994) describes such teams as providing “the vehicle for the necessary ‘right interactions’ and dialogue within R&D and among the functions that lead to on-going innovation”. Giordonan & Ahern (1994) using the Henkel Corporation as a case cites a major reason leading to quality improvement is all technical efforts are run as project teams with members from R&D, marketing, sales, technical members, and manufacturing.

Similar Engineering of Processes practices suggested by Puri (1992) include identifying all processes in the cycle, defining process boundaries and requirements for each process, and reviewing each process and taking corrective/preventive action. Other

researchers including Patino (1997) and Spain (1996) have also identified the importance of identifying R&D processes to achieving QM in R&D. The importance of identifying R&D processes to ensure that you “do it the right way the first time” has been stressed by Roberts (1991), Giordan & Ahern (1994), and Keiser & Blake (1996). Competitor benchmarking as a means of achieving quality in R&D has been identified by numerous researchers including Patino (1997), Chen & Bullington (1993), Werner & Souder (1997), and Keiser & Blake (1996).

4.1.3 – Research Evaluation Practices

Research Evaluation practices address the past accomplishments of research. Miller (1994) suggests that developing a formal system of metrics, peer reviews, and the ex-post evaluation of accomplishment are needed for the effective evaluation of research. Research Evaluation practices help to demonstrate to senior management the past impact of R&D on financial issues such as income, cost savings, and new product development.

Since Puri (1992) did not focus on R&D, he did not address the importance of evaluating research or the research scientist to achieving QM in R&D. Purdon (1996) addresses the importance of the involvement of scientists and the evaluation of their research to achieving R&D quality. Purdon (1994) suggests that scientist must develop three core competencies to help the organization achieve quality in R&D. These competencies are developing mastery of their field of science and technology, knowing and developing the core competencies essential to advancing the value-added processes of the business (e.g. improving the key manufacturing technologies), and understanding the R&D customer. Numerous researchers have also addressed the evaluation of research as an important practice for achieving QM in R&D, primarily in the areas of developing

formal metrics to evaluate research (e.g. Takahashi 1997, Werner & Souder 1997, Keiser & Blake 1996) and the ex-post evaluation of research (e.g. Werner & Souder 1997).

4.1.4 – Client Evaluation Practices

Client Evaluation practices are focused on developing effective relations between R&D department and clients. The Client Evaluation practices as identified by Miller (1994) are meetings between R&D and clients, survey of clients, and senior management assessment of research. Meetings between R&D and clients, client surveys, and senior management assessment of research allow for the definition of specifications, resolves issues, and helps to identify and address problems. Puri (1992) also addresses the importance of the customer. He suggests that partnering with customers, developing trust with customers and working with customers to identify needs and requirements are required for the successful implementation of a QM program into manufacturing organizations. Other researchers that have identified the importance of developing close working relations with the R&D client includes Werner & Souder (1997) and Patino (1997).

4.1.5 – Quality Management Practices for this Research

Since both Miller (1994) and Puri (1992) address QM practices in organizations, it can be expected that there will be overlap in some of the practices that they suggest. Table 3 shows the practices that have been addressed by both researchers.

Table 3

QM Practices Suggested by Puri and Miller

<i>Management practices suggested by Puri</i>	<i>Management practices suggested by Miller</i>
Foster management awareness / education / discussion Developing a mission statement Partner with clients Identify all processes Process improvement teams Define process boundaries Identify process control / improvement requirements Corrective/ preventive action Identify improvement opportunities Review of R&D processes Define best practices Establish measures of performance Audit/evaluation practices Cost/benefit & risk analysis Conformance to specified requirements Identifying strategic initiatives	Deliberations with top management Understanding corporate strategies (e.g. developing a mission statement, understanding the strategic purpose of R&D) Meeting with R&D and clients Survey of clients Innovation teams Modeling of processes Review of systems & processes Engineering of Process System of metrics Ex-post evaluation of research Peer reviews

Miller (1994) did not focus specifically on the R&D departments of *manufacturing* companies and therefore did not address some important management practices that this research considers. These specific practices include the need for the involvement of suppliers, the involvement of all employees (not just the research scientist) in R&D, and developing formal groups to specifically address quality in R&D (e.g. quality management steering committee). All of these management practices have been addressed by Puri (1992). In addition, Puri (1992) describes various client focused QM practices that Miller (1994) did not address. Therefore in addition to Miller's (1994) QM practices, the following practices are also addressed by this research:

- Establish a quality management steering committee
- Provide employee awareness/education on quality and quality issues.
- Partner with suppliers and identify requirements/needs
- Develop trust with suppliers
- Partner with customers and identify requirements/needs
- Develop trust with customers

The list of QM practices for this research is comprised primarily of those practices suggested by Miller (1994). However, some of his management practices need to be re-worded to either make it clear or to make it in context with R&D. One such example includes understanding corporate strategies. This practice requires examples such as developing a mission statement and understanding the strategic role of R&D to make it clear to the respondent. Another example is competitive positioning & assessment. This practice is re-worded *to determining the competitive position of R&D* and includes examples such as review of patents, publications, competitive position of the firm's technology or product. Also included in this list are practices suggested by Puri (1992) that may be relevant to R&D departments operating in a manufacturing organization. The QM practices for this research, along the question number on the survey and researchers that have suggested similar practices in an R&D context, are listed in Table 4.

Table 4

QM Practices for this Research

<i>Management practice</i>	<i>Que.</i>	<i>Similar practice suggested by</i>
Understanding corporate strategies (e.g. developing a mission statement).	1	Miller 1992, Spain 1996, Takahashi 1997, Weerd-Nederhof et al. 1997.
Identification / review of R&D strategic goals and purpose.	2,3	Miller 1992, Patino 1997, Takahashi 1997.
Review of R&D processes.	4	Miller 1992, Patino 1997, Spain 1996, Weerd-Nederhof et al. 1997, Wood & McCamey 1993.
Copying of successful R&D processes.	5	Miller 1992, Spain 1996.
Establish a quality management steering committee.	6	Keiser & Blake 1996, Roberts 1991.
Implementing an R&D process improvement team.	7	Puri 1992 (Modified to fit R&D).
Undertaking quality improvement projects.	8	Puri 1992.
Implementing a formal system of metrics.	9	Keiser & Blake 1996, Miller 1992, Takahashi 1997, Weerd-Nederhof et al. 1997, Werner & Souder 1997.
Obtaining quality certification (ISO, SEI, etc.).	10	Miller 1992, Seward 1992, Weerd-Nederhof et al. 1997.
Formal deliberations with senior managers (e.g. R&D managers and employees meeting with senior managers to discuss emerging technology).	11	Miller 1992, Patino 1997, Wood & McCamey 1993.
Senior management assessment of research.	12	Miller 1994.
Implementing exploration groups (e.g. multi-functional groups used to identify possible future markets).	13	Francis 1992, Miller 1994, Patino 1997, Wood & McCamey 1993.
Determining the competitive position of R&D (e.g. review of patents, publications, competitive position of the firm's technology or product).	14	Miller 1994, Patino 1997, Schumann et al. 1995, Takahashi 1997, Weerd-Nederhof et al. 1997, Werner & Souder 1997.
Identifying/monitoring of intellectual property	15,16	Miller 1994, Schumann et al. 1995, Weerd-Nederhof et al. 1997.
Common research databases.	17	Miller 1994, Lamb & Dale 1993.
Common research methodologies.	18	Bailetti & Yeun 1990, Miller 1994.
Effective documentation and reporting practices.	19,20	Miller 1994, Patino 1997.
Provide employee awareness / education on quality issues.	21,22	Debackere et al. 1997, Patino 1997, Szakonyi 1992, Wood & McCamey 1993.
Involving employees in R&D decision making.	23	Miller 1994 (Modified to fit R&D).
Monitoring personnel transfer.	24	Miller 1994.
Ex-post evaluation of research.	25	Miller 1994, Weerd-Nederhof et al. 1997, Werner & Souder 1997.
Reviewing conformance to requirements.	26	Puri 1992.
Partner with clients and identify requirements / needs.	27	Chen & Bullington 1993, May & Pearson 1993, Weerd-Nederhof et al. 1997.
Develop trust with clients.	28	Patino 1997.
Partner with suppliers and identify needs / requirements.	29	Debackere et al. 1997, Keiser & Blake 1996, May & Pearson 1993, Takahashi 1997.
Develop trust with suppliers.	30	Chen & Bullington 1993, Keiser & Blake 1996.

As addressed in Section 2.4, the operational definition of quality in R&D for this research is a combination of Wood & McCamey (1997) and Schumann et al. (1995) summarization of quality in R&D. This definition of quality in R&D is:

An understanding of who the R&D client is and what his or her values and expectations are, what the key technologies are and how they can be used to meet R&D clients' expectations and the needs of the entire organization, and who the R&D competitors are and how they will respond to emerging R&D clients needs. This is achieved by doing things right once you are sure you are working on the right things, concentrating on continually improving the system, enabling people by removing barriers, and encouraging people to make their maximum contribution.

Reviewing the practices in Table 5, it becomes apparent that the definition of quality in R&D has been fully captured by these practices. The table below shows a breakdown of this definition of quality along with the associated QM practice and survey questions.

Table 5

Quality Definition and Practice Mapping

Definition Component	QM Practice/s	Que.
An understanding of who the R&D client is and what his or her values and expectations are.	-Partner with clients to identify requirements/needs.	26
	-Develop trust with clients	27
What the key technologies are and how they can be used to meet R&D clients' expectations and the needs of the entire organization	-Formal deliberations with senior management (e.g. R&D managers and employees meeting with senior management to discuss emerging technology).	11
Who the R&D competitors are and how they will respond to emerging R&D clients needs.	-Determining the competitive position of R&D (e.g. Review of patents, publications, competitive position of the firm's technology or product).	14
Doing things right once you know you are working on the right things, concentrating on continually improving the system.	-Understanding corporate strategies.	1
	-Identifying / reviewing R&D strategic goals and purpose.	2,3
	-Reviewing R&D processes.	4
	-Copying successful R&D processes.	5
	-Implementing an R&D process improvement team.	7
	-Undertaking quality improvement projects.	8
Enabling people by removing barriers, and encouraging people to make their maximum contribution	-Reviewing conformance to requirements.	26
	-Implementing exploration groups (e.g. multi-functional groups used to identify possible future markets).	13
	-Providing employee awareness / education on quality issues.	21
		22
	-Involving employees in R&D decision making.	23
		24
	-Monitoring personnel transfer.	25

4.1.6 - QM Practices Model

As stated in Sections 4.1.1 through 4.1.4, Miller (1994) groups QM practices under four general practices (i.e. Strategic Analysis, Engineering of Process, Client Evaluation, Research Evaluation). In addition, Puri (1992) addresses some important Supplier Focus (e.g. partner with suppliers and identify requirements/needs, develop trust with suppliers) and Employee Focus (e.g. involving employees in R&D decision making, providing employee awareness / education on quality issues) practices that may also be important when implementing a QM program into the R&D departments of

manufacturing organizations. Combining Miller and Puri's practices, the following model is developed for testing:

Figure 3
Critical Practices for QM Implementation

4.2 - Quality Management Tools: Theoretical Framework

The QM practices established in Section 4.1 can be achieved using different QM tools. To illustrate, to identify the needs of clients some R&D departments may use client surveys, while other R&D departments may establish formal meetings with customers. Therefore, an effective QM program can be implemented using different combinations of QM tools. The various QM tools and methodologies as identified in the current research literature are listed below (Keiser & Blake 1996, Lamb & Dale 1994, Miller 1994, Puri 1992, Werner & Souder 1997):

Table 6**QM Tools**

Flow Chart	Brainstorming
Checksheet	Benchmarking
Cause-effect Diagram	Force Field Analysis
Pareto Chart	Design of experiments
Trend Chart	Concurrent engineering
Scatter Diagram	QFD
Tree Diagram	Relations Diagram
Shewhart – Deming Cycle	Control Charts
Nominal Group Technique	SPC
Block Diagram	Arrow diagram
Process Decision Program Chart	Affinity Diagram/KJ
Histogram	Matrix Diagram
Peer reviews	Cost /Benefit analysis
Customer ratings	Ex-post evaluation
Formal set of quality metrics	Cross Functional Teams
Client surveys	Monitoring of intellectual property
Formal meetings between researchers and clients	Quality Certification
Risk Analysis	Formal Quality Audit

Examining the QM tools in Table 6, it is apparent that not all of these tools apply to R&D departments. For example the use of SPC may not apply to R&D, since the output of R&D departments is knowledge and any tangible output is usually low (Exhibit 4). Similarly, a control chart may be deemed less appropriate than customer surveys, since the focus of R&D quality is the customer and control charts are used to represent data from a highly repetitious environment. Reviewing the current R&D research literature (Debackere et al. 1997, Francis 1992, Miller 1995, Schumann et al. 1995, Takahashi 1997, Werner & Souder 1997,) a number of QM tools have been cited as being used in R&D departments. This research identifies the extent of usage and the perceived appropriateness of these QM tools in the R&D departments of manufacturing organizations. The QM tools for this research along with its respective question number on the survey is identified below:

Table 7**QM in R&D Tools**

QM Tool	Question	QM Tool	Question
Pareto Analysis	1	Formal meetings between R&D and suppliers	10
Structured Diagrams	2	Peer reviews	11
Shewhart-Deming Cycle	3	Formal meetings between R&D and clients	12
Brainstorming	4	Client ratings	13
Benchmarking	5	Client surveys	14
Design of experiments	6	Formal quality audits	15
Quality Function Deployment	7	Quality certification	16
Formal set of quality metrics	8	Risk analysis	17
Formal quality objectives	9	Cost/benefit analysis	18

4.3 - Quality Management Biases in R&D: Theoretical Framework

Similar to the early notions of quality in manufacturing, quality in R&D has also been subjected to some biases. Organizations that implement QM practices into R&D are faced with the challenge of discrediting various viewpoints regarding QM and its place in R&D activities (Lamb & Dale 1994, May & Pearson 1993, Patino 1997, Tenner 1991, Wood & McCamery 1993). These common viewpoints as cited in the current literature are summarized as follows:

- A quality focus will restrict the creativity and innovating requirements of successful R&D development.
- Quality management involves only statistical and quantitative techniques and is not valid in a research environment.
- R&D activities have low tangibility with very few repetitive tasks. Therefore, manufacturing based quality techniques are not applicable to R&D departments.
- Quality management focuses on efficiency and not effectiveness.
- Research scientists consider quality to be beneath them.
- Research scientists consider quality as just the latest management fad.

This research will determine if these QM biases are found amongst R&D managers.

CHAPTER 5

RESEARCH OBJECTIVES AND QUESTIONS

The first objective of this research is to examine the activities that R&D managers perceive to be critical for the successful implementation of a QM program into R&D departments. This will help R&D managers decipher from a long list of possible QM practices those that other R&D managers believe to be critical when attempting to implement a QM program into an R&D department. The second research objective is to examine the extent of use of specific QM tools in the R&D departments of manufacturing organizations that have won national quality awards. R&D managers' perceptions towards the appropriateness of such tools in R&D departments will also be addressed. This is beneficial to R&D departments that are about to implement a QM program, since it will give managers in these departments some insight as to those specific QM tools that should be stressed and those that should be avoided. The final objective of this research is to determine if the common employee biases towards QM in R&D are also found among R&D managers. This will help R&D managers address what changes they must personally make in order for QM to succeed in R&D activities. Any QM practices, tools, and biases that are not addressed in this research is captured by allowing respondents to add additional information on the survey. Combining the three objectives of this research, the following research question emerges:

- What quality management practices and perceptions exist in the R&D departments of manufacturing-based quality award winners?

From this research question, the following investigative questions can be critically examined:

- What quality management practices do R&D managers perceive to be critical for the successful implementation of a quality management program in R&D?
- What quality management tools do R&D managers perceive to be appropriate for R&D departments?
- What QM tools are used to implement quality in R&D?
- Are the common employee biases towards quality management in R&D also found amongst R&D managers?

CHAPTER 6

RESEARCH METHODOLOGY

This research takes the form of a cross-sectional study. The study is exploratory and determines the current QM practices and perceptions in R&D activities. The research objectives in Chapter 5 were addressed using a survey questionnaire (Exhibit 5). The questionnaire was divided into four sections consisting of QM practices, tools, biases, and general information. The population and sample were chosen from both the organizational and individual level, described as follows:

Table 8 - Survey Design

ORGANIZATIONAL	DESCRIPTION
Population	Manufacturing organizations that were winners of the Canada Awards for Business Excellence, Malcolm Baldrige National Quality Award, and the Shingo Prize for Excellence in Manufacturing.
Sample	All the organizations in the population willing to participate
Sample Size	Fifty-six (56) manufacturing organizations.
Extent	Canada and the United States.
Time	Spring 1999.
INDIVIDUAL	DESCRIPTION
Population	Single most senior R&D official willing to participate.
Sample	All the firms in the organizational sample.
Sample Size	One (1) individual in the organization.
Extent	Within the organization.
Time	Spring 1999.

The primary survey instrument used was a telephone questionnaire. The secondary survey instrument was faxed questionnaire. The secondary survey instrument was used in five cases. When the faxed questionnaire survey instrument was used, a cover letter was also faxed outlining the purpose of the research and the value of the respondent's input (Exhibit 6). If the questionnaire was not returned via fax or mail within two weeks, a new letter describing the importance and relevance of the research (Exhibit 7) along with

a new questionnaire was faxed. The respondents also had the opportunity to request a copy of the survey results. Only one respondent requested a copy of the results of this research.

CHAPTER 7

DATA COLLECTION

Twenty-six third year business and information systems students were given the survey to complete and critique. On average, it took the students 10–15 minutes to complete the survey. The main complaint regarding the survey was that some of the terms were not clearly understood. The two major terms being Pareto Analysis and PDCA cycle. To solve this problem, both of these tools contain a footnote at the bottom of the survey page, giving a formal definition of the actual tool. The second complaint was that the spacing between points of the survey scale was not consistent, especially between the 4 and 5. This problem has also been corrected and is reflected in the final survey (Exhibit 5).

Data were collected between January and April 1999. The telephone surveys required a significant amount of time. The major reason for the large time frame was trying to contact an R&D manager with enough time to answer the questionnaire. The secondary data collection tools, fax survey, was used in five cases with only one survey being returned and an e-mail received from an R&D managers explaining that they didn't have enough time to answer the survey. Once organizations that won an award multiple times (e.g. Ford Electronics, Johnson Controls, Alcatel Networks, Union Carbide) and companies that openly admit that they do not answer surveys (i.e. IBM) were accounted for, the sampling frame was reduced to fifty-six organizations (Exhibit 8). Twenty-one surveys were collected (Exhibit 9) from these fifty-six organizations, resulting in a response rate of 37.5%.

CHAPTER 8

DATA ANALYSIS

In the data analysis that follows, the variables have been named in relation to their position on the questionnaire. To illustrate, P1 is the first management practice on the questionnaire, T1U is the usage of the first tool, T1A is the appropriateness of the first tool, and B1 is the first management bias. Exhibit 10 gives a list of each practice, tool, and bias on the survey and its variable name. A discussion of the research findings from this data analysis will occur in Chapter 9.

8.1 – Descriptive Statistics

The data was checked multiple times to ensure no coding errors and the absence of outliers. The minimum and maximum values for each variable were also calculated to ensure that all responses were either coded a value between 1 and 5 or remained null (Exhibit 11).

In addition to the presence of outliers, the distribution of the data must also be checked. The distribution of the data is obtained by determining the skew and kurtosis of the data for each variable. If a distribution's mean and median do not coincide, the distribution is skewed. If the distribution's mean is greater than the median then there is a positive skewness. If the distribution's mean is less than the median then there is a negative skewness (Skew and Kurtosis a Discussion 1999). Kurtosis measures how much a distribution departs from normality. Kurtosis essentially measures the thickness of the tails of the distribution (Skew and Kurtosis a Discussion 1999). To find significant

kurtosis (or skew), the kurtosis (or skew) is divided by the standard error of kurtosis (or skew). If the result is greater than 1.96 or less than -1.96 (for alpha .05) then the data is significantly kurtopic (or skewed) (Skew and Kurtosis a Discussion 1999).

Exhibit 12 displays the skewness and kurtosis for each variable, with the significantly skewed and kurtopic variables shaded. Of the seventy-two variables tested, seven variables were found to be both significantly skewed and kurtopic. These variables are: understanding corporate strategies (i.e. P1), monitoring the transfer of employees (i.e. P24), reviewing conformance to clients' requirements (i.e. P26), establishing trust with clients (i.e. P28), brainstorming (i.e. T4U), risk analysis (i.e. T17A), and quality management practices focuses only on the quality of a product or service (i.e. B6). For variables P1, P24, P26, P28, T4U, and T17A, the responses are concentrated between points 4 and 5 on the survey scale (Exhibit 13). This suggests that most R&D managers agree or strongly agree with each of these questions. The responses for variable B6 are concentrated between points 1 and 2 on the survey scale (Exhibit 13), suggesting that R&D managers either disagree or strongly disagree with this particular question. Since these managers have very strong and similar views towards these variables (i.e. P1, P24, P26, P28, T4U, T17A, and B6), the variables will remain in the study.

8.2 - Quality Management Practices Overview

To determine the validity of the proposed QM practices model (Figure 3), a number of statistical tests will be performed. Confirmatory factor analysis can not be used in this study, due to the lack of correlation matrices between the individual

management practices and the broad concepts for Supplier Focus and Employee Focus practices. Instead, a test of internal consistency will give an indication of how well each practice explains the associated factor. If the model is not internally consistent, then this gives an indication that the proposed model may not be the best model for QM in R&D. To develop a new model, a combination of one-sided Student's t-test and exploratory factor analysis will be used. Student's t-test measures the difference between the sample mean and a set parameter. For this research, the parameter is three and represents the mid-point on the survey scale. The null hypothesis to determine those QM practices that R&D managers' view to be important is stated as follows:

- **H₀:** Sample mean $\leq$ the mid-point (3) of the survey scale.
- **H_A:** Sample mean $>$ the mid-point (3) of the survey scale.
(one-sided t-test)

Factor analysis will be performed on those variables that are significant at the .05 level of significance. The resulting factors will be named and considered when developing a new model.

8.2.1 – Internal Consistency of QM Practices

The internal consistency test used for this research is Cronbach's Alpha. This test measures the internal consistency of the survey instrument where subjects respond to questions on a scale (e.g. 1-5 for this research). Cronbach's Alpha can range between 0 and 1. If Cronbach's Alpha is above .60 the survey instrument is considered to be internally consistent. The concepts measured are taken from the QM model in Section 4.2. These concepts are: Strategic Analysis, Engineering of Process, Research Evaluation, Client Evaluation, Employee Focus, and Supplier Focus practices.

8.2.1.1 - Internal Consistency of Strategic Analysis Practices

The first test of internal consistency was performed using all the Strategic Analysis QM practices, specifically P1, P2, P3, P11, P13, P14, P15, and P16. Table 9 shows the internal consistency of Strategic Analysis practices.

Table 9
Internal Consistency of Strategic Analysis Practices

	Mean	Scale	Scale	Corrected
	if Item	Variance	Item-	Alpha
	Deleted	if Item	Total	if Item
		Deleted	Correlation	Deleted
P1	26.4286	21.0571	.5521	.7815
P2	26.6190	21.4476	.4980	.7916
P3	26.9048	25.1905	.2800	.8169
P11	26.9048	23.2905	.5925	.7783
P13	27.0000	25.7000	.2649	.8167
P14	26.9524	20.8476	.7025	.7565
P15	26.8095	20.7619	.7512	.7500
P16	27.0476	22.5476	.5666	.7788

Reliability Coefficients

N of Cases = 21.0

N of Items = 8

Alpha = **.8070**

Removing variables P3 and P13 will result in an increase in alpha from .8070 to .8169 and .8167 respectively. To determine the alpha of removing both variables from the model, Cronbach's Alpha must be performed again. Performing Cronbach's Alpha with P3 and P13 removed, the following alpha is obtained:

Table 10
Internal Consistency of Strategic Analysis Practices – P03 and P13 Removed

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item- Total Correlation	Alpha if Item Deleted
P1	19.0000	15.0000	.6239	.8060
P2	19.1905	15.7619	.5144	.8319
P11	19.4762	17.6619	.5782	.8163
P14	19.5238	15.2619	.7292	.7828
P15	19.3810	15.5476	.7270	.7845
P16	19.6190	17.1476	.5328	.8220

Reliability Coefficients

N of Cases = 21.0

N of Items = 6

Alpha = .8345

Analyzing Table 10, it is shown that alpha will not increase by removing any other variables. Alpha with P3 and P13 included is internally consistent at .8070. Removing P3 and P13 will increase alpha, but only by .0325 (i.e. .8395 - .8070). In this case, it is reasonable to keep these two variables in the model. These two variables are identifying and reviewing the purpose of R&D (i.e. P3) and implementing exploration groups (i.e. P13). Pearson et al. (1998) show the strategic importance of reviewing the purpose of R&D by suggesting that divisional (e.g. R&D) strategies should be developed from the corporate strategy, once the corporate strategy, vision, and mission have all been identified. The importance of exploration groups has been suggested by Fisher et al. (1992). They suggest that the application of quality management to R&D requires “management not only to cede power and responsibility to employees but also to foster an across-the-board team approach involving all parties”. The low change in alpha as a result of removing P3 and P13, combined with the support for these practices in the

research literature, indicates that identifying and reviewing the purpose of R&D (i.e. P3) and implementing exploration groups (i.e. P13) are acceptable Strategic Analysis practices.

8.2.1.2 - Internal Consistency of Engineering of Process

The variables that make up Engineering of Process are: P4, P5, P7, P8, P10, P17, P18, P19, P20, and P24. Performing Cronbach's Alpha on these variables, the following output is obtained:

Table 11
Internal Consistency of Engineering of Process

	Mean if Item Deleted	Scale Variance if Item Deleted	Scale Item- Total Correlation	Corrected Alpha if Item Deleted
P4	32.0476	40.8476	.4828	.8390
P5	32.0000	41.5000	.4347	.8427
P7	32.3333	38.9333	.5884	.8299
P8	32.0476	38.8476	.5532	.8329
P10	32.5714	36.7571	.4800	.8469
P17	32.4286	39.5571	.5089	.8369
P18	32.5714	36.2571	.7320	.8152
P19	32.1429	34.0286	.8663	.7996
P20	31.8571	43.4286	.4180	.8445
P24	32.2857	41.6143	.4605	.8408

Reliability Coefficients

N of Cases = 21.0

N of Items = 10

Alpha = .8477

Analyzing Table 11, it is evident that removing any of the variables from the Engineering of Process broad management practice will not increase alpha. Therefore, the variables used to explain Engineering of Process are internally consistent.

8.2.1.3 - Internal Consistency of Client Evaluation Practices

Client Evaluation practices are comprised of variables P12, P26, P27, and P28.

Running Cronbach's Alpha, the following output is obtained:

Table 12
Internal Consistency of Client Evaluation Practices

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item- Total Correlation	Alpha if Item Deleted
P12	13.0000	5.0000	.1660	.8586
P26	12.1905	4.6619	.4981	.6359
P27	12.2857	3.8143	.7822	.4625
P28	11.9524	3.7476	.6544	.5241

Reliability Coefficients

N of Cases = 21.0

N of Items = 4

Alpha = .7013

Removing P12 from Client Evaluation practices will result in a substantial increase in internal consistency (i.e. from an alpha of .7013 to .8586). Client Evaluation involves developing effective relationships between the R&D department and clients. As a result, it will ultimately be the day-to-day interactions between the R&D department and the client that will determine effective client relationships. Senior management evaluation of research projects (i.e. P12) is important in R&D and may be better represented as a Research Evaluation practice instead of a Client Evaluation practice. Therefore, P12 has been removed from Client Evaluation practices and will be tested as a Research Evaluation practice in Section 8.2.1.5.

8.2.1.4 - Internal Consistency of Employee Focus Practices

Employee Focus practices comprise of variables P6, P21, P22, and P23. The internal consistency of Employee Focus practices is listed in Table 13.

Table 13
Internal Consistency of Employee Focus Practices

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item- Total Correlation	Alpha if Item Deleted
P6	12.7143	2.7143	.1166	.4737
P21	11.7143	2.5143	.4319	.0937
P22	11.5714	2.3571	.6243	-.0818
P23	11.7143	4.0143	-.1183	.6192

Reliability Coefficients

N of Cases = 21.0

N of Items = 4

Alpha = .3951

Alpha is very low for Employee Focus practices. However, removing variable P23 increases alpha from .3951 to an internally consistent alpha of .6192.

Examining the characteristics that the other practices (i.e. P6, P21, and P22) have in common, it can be argued that involving employees in R&D decision making (i.e. P23) is not an appropriate Employee Focus practice. Establishing a quality management steering committee (i.e. P6), providing employee awareness on quality issues (i.e. P21), and providing employee education on quality issues (i.e. P22) can all be used to convince employees of the importance and the need for quality in R&D. Involving employees in R&D decision making is more of a management issue that addresses who has the power to make decisions effecting the quality of R&D projects. This specific practice will have a large impact in determining whether R&D goals and strategies are met. As a result, this

practice may be better represented as a Strategic Analysis practice. Performing Cronbach's Alpha on Strategic Analysis practices and including variable P23, results in a change in alpha from .8070 to .8120. It appears from both the literature and data that involving employees in R&D decision making (i.e. P23) serves as a better Strategic Analysis practice.

8.2.1.5 - Internal Consistency of Supplier Focus & Research Evaluation

Running Cronbach's Alpha for Supplier Focus (P29, P30) and Research Evaluation (P9, P25) practices shows that Supplier Focus practices are internally consistent and Research Evaluation practices are not. Supplier Focus practices has an alpha of .6417 and is internally consistent. Research Evaluation practices, with an alpha of .5806, is not internally consistent.

It was argued in Section 8.2.1.3 that senior management evaluation of research projects (i.e. P12) is very important to achieving quality in R&D and may be better represented as a Research Evaluation practice. Performing Cronbach's Alpha on Research Evaluation practices with variable P12 included, results in a change in alpha from .5806 to .5975. Adding P12 has improved alpha, but Research Evaluation is still not internally consistent. The importance of the evaluation of research has been addressed by numerous researchers (e.g. Giordan & Ahern 1994, Patino 1997, Roberts 1991, and Tenner 1991). Therefore, those specific Research Evaluation practices that R&D managers use to achieve quality need to be determined. These practices will be determined using a combination of Student's t-test and exploratory factor analysis.

8.2.2 – Revising the QM Practices Model

The model that has been proposed in Chapter 4 is somewhat internally consistent. Some variables have been moved from one broad management practice to another. For example, involving employees in R&D decision making has been moved from an Employee Focus practice to a Strategic Analysis practice. However, the practices used to explain Research Evaluation are not internally consistent. This suggests that a better model can be developed to explain those practices that R&D managers believe are important for QM in R&D. The first step in developing such a model is to determine those specific practices that R&D managers view to be important. This is achieved using Student's t-test. Performing Student's t-test in SPSS, the following results are obtained:

Table 14
Student's t-test

QM Practice	Mean	Significance df = 20
Understanding corporate strategies	4.2381	.000
Identifying/reviewing the strategic goals of R&D	4.0476	.001
Identifying/ reviewing the purpose of R&D	3.7619	.001
Reviewing existing R&D processes	3.7619	.001
Copying successful R&D processes	3.8095	.001
Establishing a quality management steering committee	3.1905	.428
Implementing a R&D process improvement team	3.4762	.047
Undertaking quality improvement projects	3.7619	.004
Implementing formal systems of metrics	3.6190	.034
Obtaining quality certification	3.2381	.470
Conducting formal deliberation with senior managers	3.7619	.000
Having senior management evaluate research projects	3.4762	.056
Implementing exploration groups	3.6667	.002
Determining the competitive position of R&D	3.7143	.006
Identifying intellectual property	3.8571	.001
Monitoring intellectual property	3.6190	.009
Implementing common research databases	3.3810	.119
Developing common research methodologies	3.2381	.348
Documenting current practices	3.6667	.019
Ex-post evaluation of research	3.4286	.035
Monitoring the transfer of employees	3.5238	.012
Reviewing conformance to clients' requirements	4.2857	.000
Partnering with clients to identify needs / requirements	4.1905	.000
Establishing trust with clients	4.5238	.000
Implementing effective reporting practices	3.9524	.000
Providing employee awareness on quality issues	4.1905	.000
Providing employee education on quality issues	4.3333	.000
Involving employees in R&D decision making	4.1905	.000
Partnering with suppliers to identify needs / requirements	4.0952	.000
Establishing trust with suppliers	4.2381	.000

Analyzing Table 14, it becomes apparent that all but four variables are significant. The four variables that are not significant are establishing a quality management steering committee (i.e. P6), obtaining quality certification (i.e. P10), implementing common research databases (i.e. P17), and developing common research methodologies (i.e. P18).

One can only speculate, based on the comments section of the survey, why R&D managers believe that these practices are not very important for implementing quality into R&D. The first two practices, establishing a quality management steering committee

and obtaining quality certification, are very manufacturing oriented. In the open-ended section of the survey (Appendix A), a number of respondents commented very negatively on these practices. One respondent suggested that quality management steering committees along with all the quality buzzwords are just fads and that there is a need to move away from the buzzwords that exist with quality. A similar view is shared by another respondent who suggests that the quality buzzwords, such as quality management steering committee, are cynical. Yet another respondent also suggested that quality buzzwords represent fads and quite frankly suggested that managers must get through the garbage to get at the “meat”. With these views, it is possible that R&D managers may simply consider new quality developments as simply a new name for an existing QM concept.

A number of respondents also commented negatively on quality certification in R&D departments. This is best illustrated by one R&D manager whose company was ISO certified. He commented very strongly on the document burden that exists with conducting research as a result of ISO certification and felt that ISO certification represented a “quality hassle”. A similar view is shared by a company researched by Lamb & Dale (1993). This company experienced problems identifying what was required of them to introduce a quality assurance system such as ISO 9000. This company was “unsure as to whether quality assurance applies at all and ... [viewed certification] as regimentation”.

Common research databases and methodologies are viewed in the literature as important practices for achieving quality in R&D (e.g. Miller 1994). In this research however, such practices were viewed as not being important for achieving QM in R&D.

In the open-ended section of the questionnaire, none of the respondents commented on methodologies nor research databases in R&D. The poor view towards these two practices may result from R&D managers' overemphasis on the importance of implementing quality into R&D designs and not into R&D processes. Specifically, research environments (e.g. R&D, engineering) may still think "in terms of inspecting quality into their product – i.e. their designs – rather than building them into their processes" (Walton et al. 1989).

Research databases may not be viewed important to achieving quality in R&D due to concerns regarding the accuracy, appropriateness, and type of the data in the database. This is illustrated by Sakonyi (1992) who discusses a company where disputes over technology transfer occurred between the engineering department and the manufacturing department.

The essence of the dispute concerned the quality of the data that engineering would put in the database. To preserve its flexibility during the development process, the engineering department wanted to avoid getting into great detail in its designs. To make the production process as standardized as possible, manufacturing wanted all the details. Both sides found it difficult to accept the other side's demands.

(Sakonyi, 1992)

Based on the statistical data, comments from R&D respondents, and arguments from the research literature, the four practices addressed in this section, specifically, establishing a quality management steering committee (i.e. P6), obtaining quality certification (i.e. P10), implementing common research databases (i.e. P17), and developing common research methodologies (i.e. P18) will not be included when developing a new model.

8.2.3 – Factor Analysis

With the four practices (i.e. establishing a quality management steering committee, obtaining quality certification, implementing common research databases, and developing common research methodologies) removed, factor analysis can now be performed to determine the broad management practices that R&D manager's view as important for achieving quality in R&D. Running factor analysis with varimax rotation, results in six components with 79% of the variance explained. Table 15 lists the factors, associated management practices, and correlation coefficients.

Table 15

Quality Management Factors, Practices, and Correlation

Factor	QM Practice (r)
Factor 1	Conducting formal deliberation with senior managers (.728) Implementing exploration groups (.674) Identifying intellectual property (.752) Monitoring intellectual property (.855) Involving employees in R&D decision making (.870)
Factor 2	Providing employee awareness on quality issues (.899) Providing employee education on quality issues (.893) Partnering with suppliers to identify needs/requirements (.819)
Factor 3	Understanding corporate strategies (.547) Reviewing conformance to clients' requirements (.867) Partnering with clients to identify needs/requirements (.910) Establishing trust with clients (.806)
Factor 4	Implementing a R&D process improvement team (.568) Determining the competitive position of R&D (.573) Documenting current practices (.721) Monitoring the transfer of employees (.858) Ex-post evaluation of research (.766)
Factor 5	Identifying/reviewing the strategic goals of R&D (.682) Identifying/ reviewing the purpose of R&D (.708) Having senior management evaluate research projects (.737)
Factor 6	Reviewing existing R&D processes (.816) Implementing effective reporting practices (.748)

Naming these factors and developing a model from them is addressed in Chapter 9.

8.3 - QM Tools

Student's t-test will be used to determine those tools that are common and appropriate in R&D. If a large number of variables are found to be significant, then factor analysis will be used to reduce these variables to a few factors. These tests will be performed for both the usage variables (i.e. T1U – T18U) and appropriateness variables (i.e. T1A – T18A). Table 16 lists the results of performing Students t-test on the usage of QM tools.

Table 16

Student's t-test for QM Tools: Usage

QM Tool	Mean	df	Significance
Pareto Analysis	2.9048	20	.771
Structured Diagrams	3.0952	20	.680
Shewhart-Deming Cycle	2.7778	17	.466
Brainstorming	4.3333	20	.000
Competitors benchmarking	3.6190	20	.009
Formal design of experiments	3.6667	20	.012
Quality function deployment	3	20	1.000
Formal set of quality metrics	3.5238	20	.077
Formal quality objectives	4	20	.000
Formal meetings between R&D and clients	4.0952	20	.000
Peer reviews	3.6190	20	.009
Formal meetings between R&D and suppliers	3.3333	20	.167
Client ratings	2.9524	20	.867
Client surveys	2.6667	20	.260
Quality audits	3.1905	20	.550
Quality certification	3.1905	20	.576
Cost-benefit analysis	3.5714	20	.097
Risk analysis	3.4286	20	.186

Analyzing Table 16, only eight QM tools are significant at the .05 level of significance. These QM tools are: brainstorming, competitors benchmarking, formal design of experiments, formal set of quality metrics, formal quality objectives, formal meetings between R&D and clients, peer reviews, and cost/benefit analysis. Repeating the same test for the appropriateness of QM tools (T1A – T18A) the following results are obtained.

Table 17**Student's t-test for QM Tools: Appropriateness**

QM Tool	Mean	df	Significance
Pareto Analysis	3.35	19	.185
Structured Diagrams	3.3333	20	.110
Shewhart-Deming Cycle	3.2353	16	.387
Brainstorming	4.1905	20	.000
Competitors benchmarking	3.5238	20	.069
Formal design of experiments	4.0476	20	.000
Quality function deployment	3.1	19	.733
Formal set of quality metrics	3.6667	20	.027
Formal quality objectives	4.2381	20	.000
Formal meetings between R&D and clients	4.1905	20	.000
Peer reviews	4.0952	20	.000
Formal meetings between R&D and suppliers	3.5714	20	.010
Client ratings	3.65	19	.015
Client surveys	3.35	19	.232
Quality audits	3.5	19	.066
Quality certification	3.25	19	.437
Cost/benefit analysis	3.95	19	.002
Risk analysis	3.8	19	.002

Analyzing the above data, eleven QM tools were found to be significant. These QM tools are: brainstorming, competitors benchmarking, formal design of experiments, formal set of quality metrics, formal quality objectives, formal meetings between R&D and clients, peer reviews, formal meetings between R&D and suppliers, client ratings, risk analysis, and cost/benefit analysis. The current research suggests that all the QM tools presented in this study are important for achieving QM in R&D. Therefore, the use of a relatively few tools to achieve QM in R&D is rather unexpected. Chapter 9 will address the reasons and interpretations as to why there are such unexpected results.

8.4 - Quality Management Biases

The last set of statistical tests will determine those significant biases that exist among R&D managers. Due to the low number of variables (i.e. 6), factor analysis will not be used to generate any new model. The null hypothesis to identify each individual quality management bias is stated as:

- **H₀:** Sample mean $\leq$ the mid-point (3) of the survey scale.
- **H_A:** Sample mean $>$ the mid-point (3) of the survey scale.
(one-sided t-test).

None of the variables were found to be significant at the .05 level of significance, illustrated as follows:

Table 18
Student's t-test for QM Biases

QM Practice	Mean	Test Value = 3	df	Significance
QM restricts the creative req. for successful research	2.0952	-3.800	20	.001
Scientists consider quality to be beneath them	2.1429	-3.697	20	.001
QM is just the latest fad of management	1.8	-5.080	19	.000
QM focuses on efficiency and not effectiveness	2.4762	-2.137	20	.045
QM practices are quantitative based and N/A to R&D	1.8095	-8.027	20	.000
QM focuses only on the quality of a product or service	2	-4.583	20	.000

The t-values for each variable are negative, therefore the common employee biases found in R&D departments are not common among R&D managers in quality award winning manufacturing organizations. A discussion of these biases will follow in Chapter 9.

CHAPTER 9

DISCUSSION

With the statistical analysis of the data completed, attention is now focus on model development and addressing the specific issues of this research. These specific issues are determining: the management practices required for successful QM in R&D, the appropriateness and usage of QM tools in these R&D departments, and the biases that R&D managers have towards applying quality practices to research activities.

9.1 – Practices to Achieve QM in R&D

The specific practices that R&D managers believe to be important for QM in R&D are listed in Table 19.

Table 19
Practices to Achieve QM in R&D

QM Practice	
Understanding corporate strategies	Providing employee awareness on quality issues
Identifying/reviewing the strategic goals of R&D	Providing employee education on quality issues
Identifying/ reviewing the purpose of R&D	Involving employees in R&D decision making
Reviewing existing R&D processes	Monitoring the transfer of employees
Copying successful R&D processes	Ex-post evaluation of research
Implementing a R&D process improvement team	Reviewing conformance to clients' requirements
Undertaking quality improvement projects	Partnering with clients to identify needs/requirements
Implementing formal systems of metrics	Establishing trust with clients
Conducting formal deliberation with senior managers	Partnering with suppliers to identify needs requirements
Having senior management evaluate research projects	Establishing trust with suppliers
Implementing exploration groups	Monitoring intellectual property
Determining the competitive position of R&D	Documenting current practices
Identifying intellectual property	Implementing effective reporting practices

A model will now be developed to explain how these practices allow for QM in R&D to occur. In the previous chapter, factor analysis was performed with six factors resulting. To develop such a model, attention is first focused on naming these factors. Each factor, with its associated QM practices, is listed below.

Table 20
Quality Management Practices and Factors

Factor	QM Practice
Factor 1	Conducting formal deliberation with senior managers Implementing exploration groups Identifying intellectual property Monitoring intellectual property Involving employees in R&D decision making
Factor 2	Providing employee awareness on quality issues Providing employee education on quality issues Partnering with suppliers to identify needs/requirements
Factor 3	Understanding corporate strategies Reviewing conformance to clients' requirements Partnering with clients to identify needs/requirements Establishing trust with clients
Factor 4	Implementing a R&D process improvement team Determining the competitive position of R&D Documenting current practices Monitoring the transfer of employees Ex-post evaluation of research
Factor 5	Identifying/reviewing the strategic goals of R&D Identifying/ reviewing the purpose of R&D Having senior management evaluate research projects
Factor 6	Reviewing existing R&D processes Implementing effective reporting practices

9.1.1 – Factor 1: R&D Strategic Management

The first factor is comprised of five QM practices. These practices are: formal deliberations with senior managers, implementing exploration groups, identifying and monitoring intellectual property, and the involvement of employees in R&D decision making. These are the same practices that forms the Strategic Analysis practice of the QM model developed in Chapter 8. These practices are all essential to the development of R&D strategies and aligning the strategic goals of R&D with that of the entire

company. Formal deliberations with senior managers involve R&D employees and managers meeting with senior management to discuss emerging technologies. This helps the organization identify possible future markets and new long-term strategies. Such meetings also bring to light any technological opportunities that can help the organization obtain its current strategic goals. Miller (1994) also emphasizes the importance of such meetings to help in strategy development, suggesting that these deliberations help senior managers and R&D managers “close the gap between corporate needs and technological possibilities”.

In order to identify technical possibilities, teams of employees from various departments can be used via exploration groups. Such groups focus on “economic trends, sustainable advantages, potential benefits for clients, evolving technologies, etc” (Miller 1994). Exploration groups, since they are comprised of individuals from different functional areas, help to ensure that specific research supports the overall strategy of the organization. Wood & McCamey (1993) cite a case that involves the development of innovation teams to help solve problems and implement change. “Membership [in the innovation teams] spanned all levels...and there was an expectation that people would participate”.

Identifying and monitoring intellectual property allows senior managers to determine current R&D capabilities and give senior managers some insight as to whether the R&D department can meet the strategic goals required of it. To illustrate, a company that has a large amount of intellectual property on the manufacturing of computer hard drives may not be able to meet the organization’s strategic need of a focus on CD-ROM and optical technologies. Therefore, a scan of the intellectual property of an R&D

department can give senior managers an indication of the overall capability of its R&D department. Finally, employees should have some say in the long-term strategy of their organization. Involving employees in R&D decision making can increase idea generation and may lead to the development of new products, processes, or strategies.

These practices are not simply a one-time occurrence. Once the R&D strategy is determined, it must be monitored and modified to take advantage or respond to changes in the R&D internal and external environment. These are the same practices that form the Strategic Analysis practices in Chapter 8. This name (i.e. Strategic Analysis) however, may lead managers to believe that once the strategy has been identified or analyzed, there is no longer a need to focus on R&D strategies. These practices have been renamed R&D Strategic *Management* practices. R&D Strategic Management practices, are identical to R&D Strategic Analysis practices, but with a new name to emphasize that the development and monitoring of R&D strategies is an ongoing process.

9.1.2 – Factor 2: R&D Quality Awareness

The second factor comprises of three QM practices. These QM practices are: providing employee awareness on quality issues, providing employee education on quality issues, and partnering with suppliers to identify needs and requirements. These practices are a combination of the Supplier Focus and Employee Focus practices developed in Chapter 8. It may appear that these practices are unrelated and should be divided into separate groups. However, these practices are similar in that they are required to create and maintain awareness of the need for quality in the day-to-day activities of the R&D department. The broad management practice that encompasses these specific QM practices is referred to as R&D Quality Awareness.

Without education on quality issues, employees may gain the biases (i.e. Table 19) that are commonly found in R&D departments. These biases will hamper the acceptance and use of quality in the day-to-day activities of R&D staff. To prevent these biases, education on quality issues is required at the employee level of the organization. This training must be tailored to R&D employees and address “real” issues. Wood & McCamey (1993) cite a case where a company realizing that “scientists only buy in when it becomes clear that [quality management] gives them more time to ‘do science’” modified their training material to have an employee focus. The R&D department of this organization “modified the company training materials to include more relevant examples, less accent on statistics and ... admitted right up front that the plan-do-check-act cycle was a reapplication of the scientific method” (Wood & McCamey 1993).

R&D suppliers will also have an impact on the quality of day-to-day R&D activities. By partnering with suppliers, the quality goals of the R&D department can be made known early in the supply chain. As well, by partnering with suppliers, inefficiencies (e.g. arrival of late or incorrect lab supplies) can be identified and resolved in a very quick manner. The advantage of partnering with suppliers has been cited in a Proctor and Gamble case:

By negotiating with a single, “preferred” supplier, instead of the five or six previously used, first year savings in costs of testing, shipping, and administration were \$49,600 [1993 US dollars]. In addition, not a single clinical study has been delayed due to failure to clear a batch of clinical supplies on schedule

(Wood & McCamey 1993)

Lamb & Dale (1994), also using a case study, addresses how suppliers can become actively involved in the day-to-day quality of the R&D department. The R&D department in this case determines the “requirements for each different material they purchase in

terms of quantitative measurements. These descriptions are sent to suppliers for their agreement. This then forms the official quality requirement for materials supplied to the laboratory” (Lamb & Dale 1994).

9.1.3 - Factor 3: R&D Client Focus

The third factor is comprised of: reviewing conformance to client’s requirements, partnering with clients to identify needs / requirements, establishing trust with clients, and understanding corporate strategies. The first three practices are specifically used to identify the needs and requirements of clients and are the exact practices suggested for the Client Focus practices of the model developed in Chapter 8. The last practice is understanding corporate strategies.

By understanding corporate strategies, the importance of R&D in achieving the long-term company goals can be highlighted to senior managers. Senior management may not be committed to achieving QM in R&D if they do not realize the organizational benefits of doing so. Lamb & Dale (1993) cite that one of the pitfalls to avoid when implementing QM in R&D is “starting the quality process without the long-term commitment and personal leadership from management”. To achieve this long-term commitment, an understanding of R&D in the overall strategy of the organization is required. This practice, since it involves the continual monitoring of both organizational and R&D strategies by management, is better represented as an R&D Strategic Management practice. Understanding corporate strategies will therefore become an R&D Strategic Management practice. The remaining practices (i.e. reviewing conformance to client’s requirements, partnering with clients to identify needs / requirements, and establishing trust with clients) will be referred to as R&D Client Focus practices since

they are all focused on the R&D client and are identical to the Client Focus practices identified in Chapter 8.

9.1.4 – Factor 4: Research Capability Assessment

The fourth factor consists of implementing an R&D process improvement team, determining the competitive position of R&D, documenting current practices, monitoring employee transfer, and the ex-post evaluation of research. These practices are all essential for the evaluation of the general research capability of the R&D department, irrespective of any particular project that they may currently be working on. Implementing an R&D process improvement team and documenting current practices will help to identify any inefficiencies in the way in which current research is being conducted. Lamb & Dale (1993) emphasize the importance of identifying processes, procedures, and documentation in a case comparing two R&D departments:

Both companies have been aware of the fact that procedures are often ignored and usually passed on through word of mouth. They have begun to tackle this problem through the quality improvement process and are already seeing the benefits of having readable and accessible procedures.

Determining the competitive position of R&D includes reviewing patents and publications and provides a means in which to benchmark the R&D department against similar research departments and institutions. Monitoring the transfer of employees involves tracking the skills that employees bring into the R&D department. This will help to determine the capability of research staff to work on various projects or a new area of research. Finally, evaluating research after it has occurred allows for the identification of areas that need improvement and can provide a means to determine if any changes to existing R&D process have been successful.

These QM practices (i.e. R&D process improvement team, determining the competitive position of R&D, documenting current practices, monitoring employee transfer, and the ex-post evaluation of research) allow organizations to determine if their R&D department has the capability to achieve the strategic goals of the organization. This factor is therefore referred to as Research Capability Assessment.

9.1.5 – Factor 5: Additional Research Capability Assessment Practices

The quality of individual research projects will also give an indication of the general research capability of the R&D department. Factor five is comprised of identifying/ reviewing the strategic goals of R&D, identifying and reviewing the purpose of R&D, and having senior managers evaluate research projects. Identifying and reviewing the purpose and strategic goals of R&D and having senior managers evaluate research projects will ensure that specific R&D projects are done in the best interest of the organization and not necessarily in the best interest of R&D. If a large number of R&D projects are not done in the best interest of the organization, it may suggest that the R&D department does not have the knowledge or capability to achieve the strategic goals of the organization. This point is illustrated in a case by Szakonyi (1992), who:

visited an instrument company in which the engineers, most of whom were mechanical engineers, ignored for years the advances that were taken place in electronics. Eventually, the only way in which this company could remain competitive was to base its products on electronic, not mechanical, devices. Unfortunately, most of its engineers were unprepared to make the transition.

These practices are excellent indicators of the general research capability of the R&D department. The practices of factor 4 and 5 are so closely related that they will be combined to form one broad management practice. This broad management practice is

called Research Capability Assessment (i.e. the name assigned to factor 4).

9.1.6 – Factor 6: R&D Process Management

The final factor is comprised of reviewing existing R&D processes and implementing effective reporting practices. Reviewing existing R&D processes will allow for the identification of any inefficiencies or redundant tasks that may be occurring in the R&D department. By eliminating these tasks, the efficiency of R&D will improve. Tenner (1991) emphasizes the importance of identifying R&D process as a step to achieving quality in R&D:

Flowcharts were prepared to describe the overall system and identify any steps appearing to be inefficient, wasteful or redundant. Measurements were defined to quantify total performance as well as specific steps and progress within the process. Root causes of problems were distinguished from symptoms.

Once changes to a process occurs, it will need to be monitored to ensure that a positive change has been made. Implementing effective reporting practices in R&D will help to determine if changes to a particular process has been beneficial. Since these practices focused on R&D processes, the associated factor is called R&D Process Management.

9.1.7 – Quality Management in R&D Model

We now have five broad management practices that explain the specific practices that R&D managers believe are important for QM in R&D. These broad practices are: R&D Strategic Management, R&D Quality Awareness, R&D Client Focus, Research Capability Assessment, and R&D Process Management.

R&D Strategic Management practices are the same as the Strategic Analysis practices suggested by Miller (1994) and the model developed in Chapter 8. It was renamed to emphasize that this practice must be an ongoing management task. R&D Strategic Management is comprised of: conducting formal deliberations with senior management, implementing exploration groups, identifying intellectual property, monitoring intellectual property, involving employees in R&D decision making, and understanding corporate strategies.

R&D Quality Awareness combines the Supplier and Client Focus practices developed in Chapter 8. These practices are used to implement and maintain R&D quality on a day-to-day basis. The specific practices include: providing employee awareness on quality issues, providing employee education on quality issues, and partnering with suppliers to identify needs and requirements.

Client Focus involves developing effective relations with clients. These practices are the same practices as the Client Focus practices developed in Chapter 8. Client Focus practices include: reviewing conformance to client's requirements, partnering with clients to identify needs and requirements, and establishing trust with clients.

Research Capability Assessment determines the ability of the R&D department to conduct the research required to achieve the strategic goals of the organization. Research Capability Assessment involves a combination of general and project specific practices. These practices are: implementing an R&D process improvement team, determining the competitive position of R&D, documenting current practices, monitoring employee transfer, ex-post evaluation of research, identifying / reviewing the strategic goals of R&D, identifying / reviewing the purpose of R&D, and having senior management

evaluate research projects.

The last practice addressed by this research is R&D Process Management. R&D Process Management involves the management of the processes used to conduct research. (i.e. the way the research is conducted). These practices are: reviewing existing R&D processes and implementing effective reporting practices.

“R&D can no longer live in a vacuum but rather must respond to customer requirements and the need to maintain contact with those using the work” (Fisher et al. 1992). As a result, quality in R&D requires practices that interact with the R&D external environment (e.g. senior managers, suppliers, customers). Quality management practices will require different degrees of interaction with the R&D external environment to be effective. R&D practices that require a large amount of interaction with the R&D external environment are categorized as *External R&D QM Practices*. Such practices include: establishing trust with customers, implementing exploration groups, and senior management evaluation of research projects. There are also a number of practices that are more internal to R&D and do not require a large amount of interaction with the external environment. These practices are referred to as *Internal R&D QM Practices*. Examples include: reviewing existing R&D processes, implementing effective reporting practices, and the ex-post evaluation of research. Table 21, developed using a combination of statistical data analysis, qualitative arguments, and the current research literature, shows the relationship between the broad management practices, specific practices, and the research environment.

Table 21

Quality Management Practices and Environment

Quality Management Practices	
R&D Strategic Management	R&D Environment
Understanding corporate strategies	External
Conducting formal deliberation with senior managers	External
Implementing exploration groups	External
Identifying intellectual property	Internal
Monitoring intellectual property	Internal
Involving employees in R&D decision making	Internal
R&D Quality Awareness	
Providing employee awareness on quality issues	Internal
Providing employee education on quality issues	Internal
Partnering with suppliers to identify needs/requirements	External
R&D Client Focus	
Reviewing conformance to clients' requirements	External
Partnering with clients to identify needs/requirements	External
Establishing trust with clients	External
Research Capability Assessment	
Identifying/reviewing the strategic goals of R&D	External
Identifying/ reviewing the purpose of R&D	Internal
Implementing a R&D process improvement team	Internal
Having senior management evaluate research projects	External
Determining the competitive position of R&D	External
Documenting current practices	Internal
Monitoring the transfer of employees	Internal
Ex-post evaluation of research	Internal
R&D Process Management	
Reviewing existing R&D processes	Internal
Implementing effective reporting practices	Internal

This research also found four practices that are not part of any broad management practice, but are still considered important for achieving quality in R&D (i.e. the significant management practices that did not load onto a factor). These specific practices are: copying successful R&D processes, undertaking quality improvement projects, implementing a formal system of metrics, and establishing trust with suppliers. The first three practices (i.e. copying successful R&D processes, undertaking quality improvement projects, and implementing a formal system of metrics) focuses primarily on R&D processes and are therefore considered for this research to be internal R&D QM

practices. The last practice (i.e. establishing trust with suppliers) is an external R&D QM practice since it requires a large amount of interaction with the R&D external environment (i.e. R&D suppliers) to be successful.

These practices will be included in the final model, since they can indirectly lead to quality in R&D. To illustrate, by developing trust with suppliers it will be easier to partner with these same suppliers to determine their needs and requirements for quality. If R&D suppliers do not trust the R&D department then these suppliers may be reluctant to discuss their needs and requirements for quality. This is especially true if suppliers fear that the R&D department may want to determine needs and requirements in an attempt to expose supplier quality weaknesses and therefore justify the replacement of these suppliers with more 'quality conscious' ones. As a result, developing trust with suppliers will help the implementation of the partner with suppliers to identify needs and requirements QM practice. This practice (i.e. partner with suppliers to identify needs and requirements) will then directly help in the implementation of the R&D Quality Awareness broad management practice.

Using the information presented in Table 21 and the four significant management practices that did not load onto a factor (i.e. copying successful R&D processes, undertaking quality improvement projects, implementing a formal system of metrics, and establishing trust with suppliers), Figure 4 represents the completed model for this research. This model illustrates how specific QM practices can lead to a quality culture, the development of the broad QM practices, and ultimately QM in R&D departments that are focused on applied research or development activities.

Figure 4

Model for Achieving QM in R&D

The first step to achieving QM in R&D involves the identification of the R&D external environment. Identifying the R&D external environment (e.g. other departments, senior management, customers, and suppliers) will help to highlight the fact that R&D does not occur in a vacuum and must interact with its external environment to achieve quality in R&D (Fisher et al. 1992). Once QM practices have been selected, they are implemented into R&D and various areas of the R&D external environment. Implementing one or a few of these practices will not cause QM in R&D. As practices are implemented, various R&D stakeholders will begin to realize the need and benefits of having quality in R&D. This new awareness of the need and importance of quality in R&D is referred to as the *R&D Quality Culture*. “One of the most significant things that research management can do to promote quality within an organization is to establish the proper culture” (Roberts 1989). A quality culture is not in itself QM in R&D, but is rather a requirement to achieve QM in R&D (e.g. the R&D department and stakeholders must first recognize the need for quality before it can actually be achieved).

Practices that were implemented early in the effort to achieve this quality culture may eventually be replaced by more appropriate practices. To illustrate, providing employee awareness on quality issues may be one of the first practices used to introduce employees to quality in R&D. This practice may later be replaced by providing employee education on the specific details of these same quality issues. Similarly, identifying intellectual property may be an early QM practice. However, once the entire R&D intellectual property has been identified, this practice may be replaced by the monitoring of intellectual property. The view that a QM practice used to establish the quality culture may eventually be replaced by a more effective practice is indicated in Figure 4 by the

four lines with arrows at each end (i.e. $\longleftrightarrow$).

Once the R&D quality culture exists, it will be much easier to implement specific QM practices, since all parties involved will realize the benefits of these practices. As QM practices are implemented into R&D, specific combination of these practices (e.g. Table 21) will allow for the broad management practices (i.e. R&D Strategic Management, R&D Quality Awareness, Research Capability Assessment, R&D Client Focus, and R&D Process Management) to occur.

It is only when *all* of the broad management practice have been achieved and are continually used will QM in R&D actually occur. To illustrate, if the specific practices used in the R&D quality environment are only R&D Strategic Management practices, then QM in R&D will not occur. R&D Strategic Management allows for an understanding of the purpose of R&D, but simply having this understanding with no change in the day-to-day R&D activities (e.g. no R&D Quality Awareness) is not enough to allow for QM in R&D. As a result, QM in R&D will only occur once all the broad management practices exist.

R&D Strategic Management is the most crucial broad management practice for QM in R&D and will have a large effect on the other practices. R&D Strategic Management allows for senior management understanding and commitment to quality in R&D. A lack of senior management commitment to quality in R&D will have a rippling effect, as described by Pearson et al. (1998):

The [QM in R&D] problem areas cited most often, i.e. lack of senior and middle management commitment, lack of effective measures and lack of integration throughout the division would appear to be related to a number of factors including:

- A lack of senior management understanding of quality principles in terms of the full implications and demands of any successful initiative

and, as a direct result of the previous point,

- A lack of proactive planning by management for any programme of implementation, including the route to be taken, the training packages to be used, project sponsorship and the congruence between systems, structures, and quality values.
- A lack of integrating of quality issues into corporate and divisional visions, mission statements and strategies.

Figure 4 emphasizes the importance of Strategic Management practices by making its box larger than the other practices and placing all the remaining practices below it.

A review of the literature shows that no research has attempted to develop a similar model to the one presented in Figure 4. However, various researchers have shown support for different components of this model. Miller (1994) classified R&D departments into four groups. These groups are Science Frontier R&D, Revenue Dependency R&D, Cross Functionally Integrated R&D, and Strategic Change R&D. Strategic Change R&D represents the highest level of quality in R&D attainment. Strategic Change R&D requires “vertical linkages between R&D and top management and is necessary to ensure the correct choice of scientific platforms and programs. Building R&D networks and alliances with suppliers is increasingly important” (Miller 1994). These objectives can be obtained by the R&D Strategic Management and R&D Quality Awareness practices of the QM model presented in Figure 4.

Davidson & Pruden (1996) suggest a similar level of quality attainment, referred to as the Role Model stage. The key practices in this stage include: training driven by strategic objectives, cross functional teams within R&D to improve processes, research is fully integrated into the strategic planning of the business, measurements are focused on optimizing R&D processes, and R&D processes are proactively tuned to meeting customer requirements. All of these objectives can be achieved using the R&D Strategic Management, R&D Client Focus, R&D Quality Awareness, R&D Process Management, and Research Capability Assessment practices of the QM model presented in Figure 4.

9.2 – Quality Management Tools

This research presented QM tools to R&D managers to assess the usage and perceived appropriateness of these tools in R&D. The specific QM tools that are not commonly used and are viewed as inappropriate for R&D include: quality function deployment, quality certification, shewhart-deming cycle, pareto analysis, structured diagrams, client surveys, and quality audits.

Quality function deployment (QFD) and quality certification has received support in the current research literature (e.g. Francis 1992, Takahashi 1997) as tools for achieving quality in R&D. One reason for the low usage of quality certification and QFD may be due to the way they are introduced into R&D and the large document burden associated with both tools.

Since the companies under study were quality award winners, it is expected that many of these organization already are, or are in the process of becoming, quality certified in their manufacturing operations. However, quality certification in R&D must be accepted and encouraged by R&D managers and employees and not forced upon them as a result of manufacturing pursuing or obtaining such certification. Lamb & Dale (1994) cite a company:

in the process of gaining registration to BS 5882... They view quality system registration as possibility the start of greater things to come ... [However, R&D staff] are unsure as to whether quality assurance applies at all and is viewed as regimentation. Quality plans do not seem to make much sense to them because it is claimed that the future depends very much on the results from the present. They question how you can plan if you do not know what is going to happen.

The large documentation and data requirements for quality certification and QFD could also be a factor for their low usage and low popularity in R&D departments. One respondent, who commented that tasks involving large amounts of documentation and data collection are a “quality hassle”, emphasizes this view. Curtis & Ellis (1998) share a similar view, arguing that “‘consistent use’ [of QFD] has been dropping, as companies appear to have learned that judicious application is preferable to consistency. The trend of ‘no use’ is also up ... the amount of data required is a big investment – it can be overpowering”.

The low response rate for the shewhart-deming cycle and pareto analysis may be a result of the formal names that this research has given to these tools. Various respondents asked to have these tools explained to them. Once they received the explanation, they commented that they used similar tools but they were referred to by different names. It is possible that many R&D managers simply commented that they did

not use these tools, not admitting that they did not know the actual purpose of it. The unfavorable responses towards the shewhart-deming cycle and pareto analysis may have therefore been a result of a weaknesses with the survey instrument (e.g. the tools should have had more general names). As a result, responses regarding the shewhart-deming cycle and pareto analysis may not represent R&D managers true views.

Client surveys were not viewed as appropriate nor commonly used to achieve quality in R&D. The goal of client surveys is to receive feedback from the client regarding R&D activities and results. This goal however can be achieved using other methods, such as client ratings and conducting formal meetings between R&D and clients. Client ratings and formal meetings between R&D and clients are viewed as appropriate and are commonly used in R&D. Therefore, although respondents did not view client surveys as important, they do recognize the need for receiving feedback from the client to achieve quality in research activities. Similarly, structured diagrams and quality audits can be used to identify inefficiencies in the way in which research is conducted. This can also occur through other methods such as competitors benchmarking and the formal design of experiments, both of which are commonly used and viewed as appropriate for QM in R&D.

The QM tools that R&D managers actually use to achieve quality in R&D activities are listed in Table 22.

Table 22**Quality Management Tool – Usage**

Quality Management Tool – Usage
Brainstorming
Competitors benchmarking
Formal design of experiments
Formal set of quality metrics
Formal quality objectives
Formal meetings between R&D and clients
Peer reviews
Client ratings

Eleven QM tools were viewed to be appropriate for achieving quality in R&D. These tools are listed in Table 23.

Table 23**Question Management Tools – Appropriateness**

Question Management Tools – Appropriateness
Brainstorming
Competitors benchmarking
Formal design of experiments
Formal set of quality metrics
Formal quality objectives
Formal meetings between R&D and clients
Peer reviews
Formal meetings between R&D and suppliers
Client ratings
Risk analysis
Cost/benefit analysis

Analyzing Tables 22 and 23, it is evident that R&D managers view the current tools they use as being appropriate for achieving quality in R&D. What is interesting however, is the presence of three additional tools that R&D managers view to be appropriate but are not widely used in R&D. These three tools are formal meetings between R&D and suppliers, cost benefit analysis, and risk analysis. Cost benefit analysis and risk analysis are tools that help to determine whether to proceed with a particular project. Although R&D managers believe that such practices are appropriate to achieving quality in R&D, these practices have not been widely adopted among the R&D

departments of quality committed manufacturing organizations. Such measurements of quality in R&D have “clearly been a stumbling block in getting <quality management> accepted in R&D” (Wood & McCamey 1993).

The tools that R&D managers’ use and believe are appropriate to achieving quality in R&D are brainstorming, competitors benchmarking, formal design of experiments, formal set of quality metrics, formal quality objectives, formal meetings between R&D and clients, peer reviews, and client ratings. All of these practices have been referred in the current literature as being used to achieve quality in research environments.

Brainstorming, competitors benchmarking, and peer reviews have been constantly emphasized as being effective R&D quality tools. Liebeskind (1998), however, warns that for benchmarking:

A key requirement is to be very focused on exactly what needs to be changed and to benchmark the best of the best, regardless of their business. Benchmarking is often misused and benchmark visits in some cases turn out to be merely feel-good sessions. If you are going to benchmark, do your homework before making any visits.

R&D departments should address the effectiveness of current benchmarking practices. If benchmarking and similar tools can result in “merely feel good sessions” then additional research should be focused on the success of benchmarking in actually improving R&D processes. Peer reviews has quite a lot of support in the current research literature as being an effective tool for achieving R&D quality. Werner & Souder (1997) suggest that “due to their technical expertise and familiarity with the work, professional colleagues are often in an excellent position to be assessors”.

Formal meetings between R&D and clients and client ratings are tools that focus on the client. The importance of the clients have been identified in almost every piece of research literature written regarding quality in R&D. Therefore, there is very much support in the current literature for the use of client meetings and ratings to achieve quality in R&D.

Formal sets of metrics, design of experiments, and quality objectives have also been suggested by many researchers (e.g. Curtis & Ellis 1998, Tenner 1991, Werner & Souder 1997) as tools to achieve quality in R&D. Again, Liebeskind (1998) warns that metrics must “be clear and understood by everyone or else there will be arguments later as to whether or not the goals of a given project have been met”. A similar view is shared by Tenner (1991) who suggests that counting measurements (e.g. number of patents, publications) “do not address the core interests and expectations of the customers. “High” counts may correlate with valuable R&D results, but they are not direct measures of it”.

R&D managers must take care in determining which specific metrics to use. They must ensure that any metrics adopted actually measures R&D performance and that these metrics are supported by individuals in the R&D department. To determine what specific metrics to implement, Tenner (1991) suggests that organizations should adopt a performance measurement paradigm consisting of four steps, identified as:

1. Every product and service can be described by a set of performance characteristics.
2. Your job begins by identifying your customers needs and the set of characteristics applicable to your product or service.
3. You must next translate these characteristics into process measures, and for each measure learn the performance level which your process is capable of delivering.
4. You must then understand how satisfied customers are with existing performance levels, and the relative importance they attach to changing the level of each.

Tenner (1991), suggests that using multiple metrics and not just a single one is needed in R&D. Such a viewpoint is also suggested by Curtis and Ellis (1998) who found that a customer satisfaction index, comprising of several metrics and sub-metrics, enhanced overall customer satisfaction, speed-to-market, and financial performance.

9.3 – Quality Management Biases

Statistical analysis of the QM biases (i.e. Table 18) shows that none of the biases are significant and the t-values are negative. This tells us that R&D managers disagree with the common biases that exist in R&D, these biases are:

- A quality focus will restrict the creativity and innovating requirements of successful R&D development.
- Quality management involves only statistical and quantitative techniques and is not valid in a research environment.
- R&D activities have low tangibility with very few repetitive tasks. Therefore, manufacturing based quality techniques are not applicable to R&D departments.
- Quality management focuses on efficiency and not effectiveness.
- Research scientists consider quality to be beneath them.
- Research scientists consider quality as just the latest management fad.

The fact that the companies under study were already committed to quality (e.g. they have won an award for quality) may have had a large impact for the reason why R&D

managers do not have these biases. Quality management is an organization-wide commitment, therefore it would be expected that R&D managers in these organizations would at least understand the importance of quality in R&D, even though they may not be completely sure of how to implement it. This idea was emphasized by one respondent who commented that quality is company-wide and should not be viewed as separate units in each business function. Instead, this respondent suggested that quality, regardless of the business function, involves the continual improvement of business practices and procedures. During the interviews, most respondents commented on the importance of quality in R&D. One respondent commented that quality in R&D is very important and must be managed properly. Another respondent commented on the importance of R&D designing quality into the product. From the respondents' comments, it is apparent that R&D managers have an appreciation for quality in R&D, but many also have concerns regarding how to implement it. This is shown by one respondent who commented that quality in R&D is appropriate but very hard to identify. Another respondent simply commented that quality in R&D is "a good thing" but it is "tough and a lot of work".

Wood & McCamey (1993) suggest that having directors as role models and getting managers 'on board' is critical for quality in R&D. This research has shown that directors and managers do view quality in R&D as positive to the department and are 'on board' when it comes to applying quality to research activities.

This research did not attempt to obtain the views of employees in these companies. As a result, we do not know if employees in these quality committed organizations share managers' views towards quality. What is now needed is additional research to determine if managers' views towards quality in research are being properly

disseminated to the R&D employees. There are a number of factors that could cause managers to refer positively to QM but not employees. One of these possible factors was recognized in speaking to one respondent. This respondent when asked if they used quality function deployment, commented on the fact that himself along with other managers have received the training, but it is not currently being used in his department. Although this manager has received training on quality, it is possible that most of this knowledge has not been disseminated to the employees since the technique is not being used.

It is the role of managers to implement and maintain QM practices in R&D. There are two possible reasons why an R&D manager after receiving quality training may not disseminate this knowledge to employees. These reasons are a lack of understanding of how the quality technique should be modified to be appropriate to R&D and what specific problems can the particular QM practice solve.

R&D managers must realize that quality management is not simply an abstract concept, but rather “needs to be understood as a working model or way of life for daily R&D operations”. The problem with this idea is that most quality programs are focused on manufacturing, without highlighting how quality concepts and techniques must change to function in a research environment. It is possible that the R&D manager may not understand how quality techniques can actually be applied to a research environment even though they may have gained an understanding of the importance of quality. This issue is highlighted by Wood & McCamey (1993) using Proctor and Gamble as a case:

Our training had two key features 1) it was focused on business needs and 2) it was tailored to the audience. These features reflected the lessons we learned from other parts of the company; e.g., training that was not focused on real business issues lacked buy-in, and a training program developed for manufacturing could not be transplanted wholesale into an R&D organization.

Therefore, research is required on the ability of current quality training programs to provide effective training for R&D directors, managers, and employees.

CHAPTER 10

CONCLUSION

The “slow speed of quality deployment within R&D is a critical issue worthy of further study” (Patino 1997). This research addresses this issue by examining the QM practices R&D managers use to achieve quality in R&D, the perceived appropriateness and usage of specific QM tools in R&D, and management biases towards applying quality in R&D.

This research developed an initial model integrating practices suggested by Miller (1994), Puri (1992), as well as other researchers. These practices are: Strategic Analysis, Engineering of Processes, Client Focus, Employee Focus, and Research Evaluation practices. The major problem with this model was that the Research Evaluation practices were not internally consistent, suggesting that a better model could be developed.

A final model was developed using a combination of data analysis (i.e. Student’s t-test and factor analysis), citations from the research literature, and reasoning. The final model for this research is also comprised of five broad management practices. These practices are: R&D Strategic Management, R&D Process Management, R&D Quality Awareness, R&D Client Focus, and Research Capability Assessment. The resulting model explains how specific QM practices will lead to QM in R&D. This model not only considers these QM practices, but also takes into account the R&D external environment and the importance of establishing a quality culture.

The identification of the R&D external environment is the first step in achieving QM in R&D. Identifying the R&D external environment will help highlight the fact that R&D does not occur in a vacuum. Once QM practices have been identified, they are

implemented into R&D and various areas of the R&D external environment. As practices are implemented, the groups that interact with R&D (i.e. R&D stakeholders) will begin to realize the benefits of having quality practices applied to research activities. An R&D culture will begin once the R&D department and stakeholders realize the benefits of quality in R&D. Practices that were implemented early in the effort to achieve this quality culture may eventually be replaced by more appropriate practices. Once an R&D quality culture exists it will be much easier to implement specific QM practices, since all parties involved will realize the benefits of such practices. As these QM practices are implemented into the R&D quality environment, specific combination of practices will allow for the broad management practices (i.e. R&D Strategic Management, R&D Quality Awareness, Research Capability Assessment, R&D Client Focus, and R&D process management) to occur. Once all of the broad management practice have been achieved and are continually used will quality management in R&D actually occur. Although no one has suggested a similar model, various researchers (e.g. Davidson & Pruden 1996, Miller 1994) have suggested some similar components of this particular QM model.

Quality management tools were also presented to R&D managers to get their views towards the usage and appropriateness of such tools in R&D. A number of tools were not used and viewed as inappropriate. Arguments for why these tools were not used ranged from the document burden associated with some tools (e.g. quality certification) to a possible weakness with the survey instrument (e.g. pareto analysis). Overall, eight tools were found to be commonly used and appropriate for R&D. These tools are: brainstorming, competitors benchmarking, formal design of experiments, formal set of

quality metrics, formal quality objectives, formal meetings between R&D and clients, peer reviews, and client ratings. In addition to these tools, three other tools were viewed to be appropriate for R&D, although not commonly used. These three tools are: formal meetings between R&D and suppliers, cost benefit analysis, and risk analysis. The research literature suggests that such tools have been very hard to implement into R&D.

A review of the literature showed that certain biases exist regarding the application of quality practices to R&D. These biases are:

- A quality focus will restrict the creativity and innovating requirements of successful R&D development.
- Quality management involves only statistical and quantitative techniques and is not valid in a research environment.
- R&D activities have low tangibility with very few repetitive tasks. Therefore, manufacturing based quality techniques are not applicable to R&D departments.
- Quality management focuses on efficiency and not effectiveness.
- Research scientists consider quality to be beneath them.
- Research scientists consider quality as just the latest management fad.

This research showed that R&D managers do not share these common views. It appears from the data analysis and respondents' comments that many R&D managers have an appreciation for quality in R&D, but also realize that QM in R&D is a very difficult task to achieve. This research also questioned whether R&D managers are properly communicating quality ideas to their employees.

10.1 - Future Research

Two general research questions have been developed from the data analysis (i.e. Chapter 8) and discussion (i.e. Chapter 9) chapters of this research that deserve further study and would make excellent future research initiatives. These questions focus on the current training programs and information systems in R&D departments.

The first question deals with the effectiveness of benchmarking in a research environment. In Chapter 9, it was highlighted that Liebeskind (1998) warns that for benchmarking:

A key requirement is to be very focused on exactly what needs to be changed and to benchmark the best of the best, regardless of their business. Benchmarking is often misused and benchmark visits in some cases turn out to be merely feel-good sessions. If you are going to benchmark, do your homework before making any visits.

There is little scientific research regarding the effectiveness of benchmarking in R&D and the way benchmarking should be implemented into research environments. Therefore, the following research questions arising from the discussion of QM tools, should be addressed at some point in the future:

- What is the effectiveness of benchmarking as a tool for achieving quality management in a research environment?
- What factors facilitate or hamper the implementation of benchmarking into R&D?

It was also mentioned in Chapter 9 that much of the quality training that R&D managers take may not focus on R&D. On the other hand, Wood & McCamey (1993) make the importance of training very clear, suggesting that:

Our training had two key features 1) it was focused on business needs and 2) it was tailored to the audience. These features reflected the lessons we learned from other parts of the company; e.g., training that was not focused on real business issues lacked buy-in, and a training program developed for manufacturing could not be transplanted wholesale into an R&D organization.

Current R&D training courses may emphasize concepts that do not apply in R&D (e.g. do it right the first time and SPC) or may not be focused on specific business needs. Therefore, additional research is also needed to determine the changes required to manufacturing-based quality training programs to make them more applicable to R&D departments. Such topics can be explored via the following research question:

- What specific changes are required to quality training programs to make them more appropriate and effective for R&D departments?

“Technological advances make information technology potentially the single most efficient resource for improving a business...but knowledge and mastery of information resources remains a scarce asset” (Francis 1992). During the interviews, one R&D manager commented that access to the Internet has been very “helpful” in their R&D department. The respondent commented that Internet and e-mail allowed for faster data collection and allowed for the sharing of information with the client and other departments. Many organizations however, still do not permit their employees access to the Internet due to productivity and security issues.

The use of information technology, specifically CAD, has been addressed in the research literature by Szakonyi (1992). Szakonyi (1992) citing Adler (1989) and Majchrzak & Salzman (1989) argues that “productivity increases stemming from CAD/CAM has been modest ... and the process of developing new products had not been significantly helped”. Szakonyi (1992) suggests the reason for the failure of CAD/CAM

is “that managers in the companies that use CAD/CAM have not adequately taken into account issues concerning management and organizational change. Instead, company managers have focused almost entirely on the technical aspects of CAD or CAD/CAM.”

Many organizations are therefore not fully utilizing information technologies that can directly or indirectly increase the quality of R&D activities. If R&D departments and the entire organization do not understand quality in R&D, then it is possible that their existing information systems may not allow for quality in R&D to occur. Therefore, the following research questions regarding the information systems in R&D also needs to be considered:

- Do current information technologies (e.g. CAD/CAM, Internet, Databases, E-mail) facilitate the quality implementation and QM in R&D?
- What are the requirements of information systems to facilitate QM of research activities?

10.2 - Assumptions and Limitations

The two major limitations of this study are the possibility of low generalizability and the assumption that award winners are still focused on quality. Although the response rate of the survey was high at 37.5%, the absolute number of observations (i.e. 21) is very low. In addition, seven variables had significant kurtosis and skew. These factors may result in low generalizability of this study. Another limitation involves the analysis and conclusions regarding pareto analysis and the stewhart-deming cycle. Managers may not have understood the meaning of these two tools. Therefore, the results from the data analysis may not represent R&D managers' views towards these two QM tools.

This research addresses R&D departments that are focused on applied research and development activities. As a result, this study may have limited applicability to R&D departments that are focused on basic research. Finally, this research addressed formal communication methods such as formal meetings with suppliers, customers, or senior managers. This research did not consider informal meetings, which may also have an impact on achieving QM in R&D.

Many organizations still view quality as a one-time management goal. Once quality is obtained, you no longer need to focus on developing quality and improving existing systems. As a result, a major assumption of this research is that the winners of the various quality awards actually have QM practices in place, are using these quality practices to their fullest extent, and are focused on continually improving the quality of their products and processes.

10.3 - Implications of this Research

The major benefit of this study is that it adds to the body of knowledge in the area of QM in R&D by:

- Developing a QM implementation model that highlights the relationship between QM practices, the R&D external environment, and the need for a quality culture.
- Determining the QM tools used to implement QM in R&D.
- Verifying that the common biases regarding QM in R&D are not found among the R&D managers of national quality award winning manufacturing organizations.

In addition to the immediate benefit to the R&D academic community, this research also provides a starting point for studying quality implementation issues in other non-

production areas, such as accounting, finance, or information systems.

This research is also beneficial to R&D managers. The QM implementation model is developed using data from quality committed organizations. This is beneficial to managers attempting to implement QM into their R&D department, as it will give them insight as to what practices to emphasize and avoid. The model also shows the importance of the R&D external environment in achieving QM in R&D, suggesting that the success of QM implementation depends upon a number of factors outside the immediate control of the R&D manager. This research, by addressing management biases and QM tools, helps to highlight the personal and departmental changes that R&D managers must make to successfully implement QM into R&D.

Overall, this research provides to academics and managers an awareness of the need for QM in R&D and guidance on how to achieve this difficult, yet critical, organizational goal.

11.0 - EXHIBITS

Exhibit 1: Deming's 14 Points

Point	Summary
1	Constancy of purpose toward improvement of product and services.
2	Adopt the new philosophy.
3	Cease dependence on mass inspection.
4	Eliminate suppliers that cannot provide statistical evidence as a measure of quality.
5	Actively look for problems.
6	Institute modern methods of training on the job.
7	The responsibility of the foreman must be focused on quality and not just numbers.
8	Drive out fear so that all employees will work effectively for the company.
9	Break down barriers between departments.
10	Eliminate goals that provide no method for achievement.
11	Eliminate work standards that prescribe numerical quotas.
12	Remove barriers that prevent pride employee of workmanship.
13	Institute a vigorous program for education and training.
14	Create a structure in top management that will push everyday the above 13 points.

(Stevenson 1996)

Exhibit 2: Absolutes of Quality Management

<i>Description</i>
Quality means conformance to requirements not elegance.
There is no such thing as a quality problem.
There is no such thing as the economics of quality; doing the job right the first time is always cheaper.
The only performance measurement is the cost of quality, which is the expense of non-conformance.
The only performance standard is zero defects.

(Evans & Lindsay 1999)

Exhibit 3: Basic Elements of Improvement

Element	Description
Determination	Top management must be committed to quality improvement.
Education	Everyone in the organization should understand the absolutes of quality.
Implementation	Everyone should understand how to implement quality into their activities.

(Evans & Lindsay 1999)

Exhibit 4: R&D vs. Other Areas

(Tenner 1991)

Exhibit 5: Quality Management Survey

Survey Instructions

Please read the following instructions before proceeding with this survey.

- Do not write your name on the survey.
- Mark only one response for each question.
- You will have the opportunity to provide your written comments on the last page of this survey.
- You will have the opportunity to request a copy of the results of this research
- Results of individual surveys are confidential and at no time will the information collected be disclosed to any outside parties.
- For this survey quality in R&D is defined as:

An understanding of who the R&D client is and what his or her values and expectations are, what the key technologies are and how they can be used to meet R&D clients' expectations and the needs of the entire organization, and who the R&D competitors are and how they will respond to emerging R&D clients needs. This is achieved by doing things right once you are sure you are working on the right things, concentrating on continually improving the system, enabling people by removing barriers, and encouraging people to make their maximum contribution.

Before you begin this survey, please answer the following question:

- Are you an R&D director, R&D manager, or are directly responsible for R&D strategic decision making.

YES ☐

NO ☐

If you marked **YES**: Please continue with this survey.

If you marked **NO**: Thank you for your interest and time, however this survey is intended only for R&D managers or R&D directors. Please forward this survey to the senior most R&D official in your organization.

Critical Practices for Successful Quality Management

The information gathered from these questions will improve our understanding of the critical management practices required for the successful implementation of a quality management program into R&D departments.

Please circle the number that best fits your views on each of the following steps as it relates to the successful implementation of a quality management program into R&D departments.

	<table> <tr> <th>Not Important</th> <th></th> <th></th> <th></th> <th>Very Important</th> </tr> </table>					Not Important				Very Important
Not Important				Very Important						
MANAGEMENT PRACTICES										
1. Understanding corporate strategies (e.g. developing a mission statement).	1	2	3	4	5					
2. Identifying/reviewing the strategic goals of R&D.	1	2	3	4	5					
3. Identifying/reviewing the purpose of R&D.	1	2	3	4	5					
4. Reviewing existing R&D processes	1	2	3	4	5					
5. Copying successful R&D processes	1	2	3	4	5					
6. Establishing a quality management steering committee.	1	2	3	4	5					
7. Implementing a R&D process improvement team.	1	2	3	4	5					
8. Undertaking quality improvement projects.	1	2	3	4	5					
9. Implementing formal systems of metrics.	1	2	3	4	5					
10. Obtaining quality certification (e.g. ISO, SEI)	1	2	3	4	5					

	<div> <div>Not Important</div> <div>Very Important</div> </div>				
11. Conducting formal deliberations with senior managers (e.g. R&D managers and employees meeting with senior managers to discuss emerging technologies)	1	2	3	4	5
12. Having senior management evaluate research projects.	1	2	3	4	5
13. Implementing exploration groups (e.g. multi-functional teams used to identify possible future markets)	1	2	3	4	5
14. Determining the competitive position of R&D (e.g. review of patents, review of publications, determining the competitive position of the firms technology or product)	1	2	3	4	5
15. Identifying intellectual property.	1	2	3	4	5
16. Monitoring intellectual property	1	2	3	4	5
17. Implementing common research databases	1	2	3	4	5
18. Developing common research methodologies	1	2	3	4	5
19. Documenting current practices	1	2	3	4	5
20. Implementing effective reporting practices	1	2	3	4	5
21. Providing employee awareness on quality issues.	1	2	3	4	5
22. Providing employee education on quality issues.	1	2	3	4	5
23. Involving employees in R&D decision making.	1	2	3	4	5
24. Monitoring the transfer of employees	1	2	3	4	5
25. Ex-post evaluation of research	1	2	3	4	5

	Not Important			Very Important	
26. Reviewing conformance to clients' requirements.	1	2	3	4	5
27. Partnering with clients to identify needs/requirements	1	2	3	4	5
28. Establishing trust with clients	1	2	3	4	5
29. Partnering with suppliers to identify needs/requirements.	1	2	3	4	5
30. Establishing trust with suppliers	1	2	3	4	5

You are invited to add additional **quality management practices** that you believe are required for the successful implementation of a quality management program into R&D departments.

31. Other (<i>Please specify</i>) _____ _____	1	2	3	4	5
32. Other (<i>Please specify</i>) _____ _____	1	2	3	4	5
33. Other (<i>Please specify</i>) _____ _____	1	2	3	4	5
34. Other (<i>Please specify</i>) _____ _____	1	2	3	4	5
35. Other (<i>Please specify</i>) _____ _____	1	2	3	4	5

Existing Quality Management Tools

The information gathered from these questions will improve our understanding of the current quality tools that exist in the R&D departments of manufacturing-based organizations, and the appropriateness of such tools.

Please circle the number that best shows the extent of usage and appropriateness of the following quality tools in your R&D department.

	Never Used					Always Used					Not At All Appropriate					Very Appropriate				
1. Pareto Analysis ¹	1	2	3	4	5						1	2	3	4	5					
2. Structured diagrams (e.g. histograms, tree diagrams)	1	2	3	4	5						1	2	3	4	5					
3. Shewhart-Deming Cycle (PDCA Cycle) ²	1	2	3	4	5						1	2	3	4	5					
4. Brainstorming	1	2	3	4	5						1	2	3	4	5					
5. Competitors Benchmarking	1	2	3	4	5						1	2	3	4	5					
6. Formal design of experiments	1	2	3	4	5						1	2	3	4	5					
7. Quality Function Deployment ³	1	2	3	4	5						1	2	3	4	5					
8. Formal set of quality metrics	1	2	3	4	5						1	2	3	4	5					
9. Formal quality objectives	1	2	3	4	5						1	2	3	4	5					
10. Formal meetings between R&D and clients	1	2	3	4	5						1	2	3	4	5					

1: A technique of classifying cases according to the degree of importance and focusing on resolving the most important. Pareto Analysis is based on the idea that approximately 80 % of the problems come from 20 % of the items.

2: A conceptual basis for continuous improvement comprising of creating a plan, implementing the plan, checking the results of the original goals, and acting if results are not as expected.

3: A client-driven planning process to guide the design, manufacturing, and marketing of goods. Through QFD, every design, manufacturing, and control decision is made to meet the expressed needs of clients.

	Never Used					Always Used					Not At All Appropriate					Very Appropriate				
11. Peer reviews	1	2	3	4	5						1	2	3	4	5					
12. Formal meetings between R&D and suppliers	1	2	3	4	5						1	2	3	4	5					
13. Client ratings	1	2	3	4	5						1	2	3	4	5					
14. Client surveys	1	2	3	4	5						1	2	3	4	5					
15. Quality audits	1	2	3	4	5						1	2	3	4	5					
16. Quality certification	1	2	3	4	5						1	2	3	4	5					
17. Risk analysis	1	2	3	4	5						1	2	3	4	5					
18. Cost/benefit analysis	1	2	3	4	5						1	2	3	4	5					

You are invited to add additional **quality management tools** that you are currently using in your R&D department.

19. Other (<i>Please specify</i>)	1	2	3	4	5						1	2	3	4	5					
20. Other (<i>Please specify</i>)	1	2	3	4	5						1	2	3	4	5					
21. Other (<i>Please specify</i>)	1	2	3	4	5						1	2	3	4	5					
22. Other (<i>Please specify</i>)	1	2	3	4	5						1	2	3	4	5					
23. Other (<i>Please specify</i>)	1	2	3	4	5						1	2	3	4	5					

Views Towards Quality Management in R&D

The information gathered from these questions will improve our understanding of managers' views towards the application of quality management practices and techniques to R&D activities.

Please circle the number that best indicates the level of your agreement with the following statements.

	Strongly Disagree		Neither Disagree nor Agree		Strongly Agree
1. Quality management practices restrict the creative requirements for successful research.	1	2	3	4	5
2. Scientists consider quality to be beneath them.	1	2	3	4	5
3. Quality management is just the latest fad of management.	1	2	3	4	5
4. Quality management focuses on efficiency and not effectiveness.	1	2	3	4	5
5. Quality management practices are quantitative based and are therefore not applicable to R&D.	1	2	3	4	5
6. Quality management practices focus only on the quality of products/services.	1	2	3	4	5

You are invited to add additional views that you have towards the application of quality management practices and techniques to R&D activities.

7. Other (<i>Please specify</i>) _____	1	2	3	4	5
8. Other (<i>Please specify</i>) _____	1	2	3	4	5
9. Other (<i>Please specify</i>) _____	1	2	3	4	5

Exhibit 6: Cover Letter for the First Faxed Questionnaire

XXXXXXXXXXXXXX
 XXXXXXXXXXXXXXXX
 XXXXXXXXXXXXXXXX

Month Day, 1999

XXXXXXXXXXXXXX
 XXXXXXXXXXXXXXXX
 XXXXXXXXXXXXXXXX

Dear XXXXXXXXXXXX,

I am presently conducting a survey on quality management practices and perceptions in the R&D departments of manufacturing companies that have won national quality awards. The specific issues that will be addressed include:

- What quality management practices do R&D managers perceive to be critical for the successful implementation of a quality management program in R&D?
- What quality management tools do R&D managers perceive to be appropriate for R&D departments?
- What QM tools are used to implement quality in R&D?
- Are the common employee views towards quality management in R&D also found amongst R&D managers?

This research will form part of my Master degree in Management Studies at Carleton University, Ottawa, Canada.

Since your organization was a winner of the XXXXXXXXXXXXXXXXXX award, I would ask you to please complete the enclosed survey and return it either via fax or mail. You will also have an opportunity to provide your input as well as request a copy of a report outlining the results of the survey.

Results of individual surveys are confidential and will not be disclosed to any outside parties.

Thank you for your time and input.

Todd Boyle
encl.

Exhibit 7: Cover Letter for the Second Faxed Questionnaire

XXXXXXXXXXXXXXXXXXXX
 XXXXXXXXXXXXXXXXXXXX
 XXXXXXXXXXXXXXXXXXXX

Month Day, 1999

XXXXXXXXXXXXXXXXXXXX
 XXXXXXXXXXXXXXXXXXXX
 XXXXXXXXXXXXXXXXXXXX

Dear XXXXXXXXXXXX,

Two weeks ago, you were faxed a survey regarding quality management practices and perceptions in the R&D departments of manufacturing companies that have won national quality awards.

We have not yet received your survey. I would like to stress the benefit of this research and the importance of your input. This research will give insight into the existing quality management practices that are found in R&D departments such as your own. This will provide you with a benchmark to compare quality management practices in your department to the common industry practices.

I have faxed a new survey. Please take a few minutes to complete the survey and return it at your convenience.

If you have already returned the survey please disregard this letter.

Results of individual surveys are confidential and will not be disclosed to any outside parties.

Thank you for your time and input.

Todd Boyle
encl.

Exhibit 8: Sampling Frame

Award Year	Company Name
S	1998 Coach Manufacturing Plant
S	1998 Freudenberg - NOK, Gasket Lead Center
S	1998 Johnson Controls, Inc. – Automotive Systems Group
S	1998 Lear Corporation
S	1998 Milwaukee Electric Tool Corporation
S	1997 Champion International Corporation
S	1997 Perfecseal, A Bemis Company
S	1997 TechnoTrim
S	1996 Eaton Yale Ltd.
S	1996 Ford Cleveland Engine Plant 2
S	1996 Merix
S	1995 LifeScan Inc. - A Johnson & Johnson Company
S	1995 Mascotech – Braun
S	1995 Nucor -Yamato Steel
S	1995 The Foxboro Company - I/A Division
S	1995 Vintec
S	1994 Alcatel Networks Systems, Inc.
S	1994 Lucent Technologies Microelectronics Group
S	1994 General Tire Inc.
S	1994 Johnson & Johnson Medical – Vascular Access
S	1994 The Timken Company
S	1994 Union Carbide Ethyleneamines Business
S	1993 Gates Rubber Company
S	1993 Wilson Sporting Goods
S	1992 Lucent Technologies
S	1992 Iomega Corporation
S	1991 Dana Mobile Fluid Products Division
S	1991 Exxon Chemical Butyl Polymers - Americas
S	1991 Glacier Vandervell Inc.

Award Year	Company Name
C	1996 Baxter Corporation – Alliston Plant
C	1996 KI Pembroke
C	1996 Harris Farincn Canada
C	1993 Ford Electronics Manufacturing Corporation
C	1992 Chrysler Canada, Ltd.
C	1992 Linamar Machine Limited
C	1990 Miliken Industries of Canada Ltd.
C	1990 Northern Telecom Canada Limited
C	1989 Xerox Canada, Ltd.
C	1989 Henderson Barwick, Inc
C	1988 Du pont Canada, Inc.
C	1987 Fishery Products International Limited
C	1985 Garrett Canada
B	1997 3M Dental Products Division
B	1996 ADAC Laboratories
B	1995 Armstrong World Industries, Inc.
B	1995 Corning Incorporated
B	1993 Eastman Chemical Company
B	1992 AT&T Network Systems Group
B	1992 Texas Instruments Incorporated
B	1991 Solectron Corporation
B	1991 Zytec Corporation
B	1990 Cadillac Motor Car Company
B	1989 Milliken & Company
B	1988 Motorola, Inc.
B	1988 Westinghouse Electronic Corp.

Exhibit 9: List of Respondents

Award Year	Company Name
S	1998 Milwaukee Electric Tool Corporation
S	1997 Perfecseal, A Bemis Company
S	1996 Merix
S	1995 Mascotech – Braun
S	1995 The Foxboro Company - I/A Division
S	1993 Wilson Sporting Goods
S	1992 Iomega Corporation
S	1991 Exxon Chemical Butyl Polymers - Americas
S	1991 Glacier Vandervell Inc.
C	1996 KI Pembroke
C	1992 Linamar Machine Limited
C	1990 Northern Telecom Canada Limited
C	1989 Henderson Barwick, Inc
C	1988 Du pont Canada, Inc.
C	1987 Fishery Products International Limited
B	1997 3M Dental Products Division
B	1996 ADAC Laboratories
B	1995 Armstrong World Industries, Inc.
B	1992 Texas Instruments Incorporated
B	1989 Milliken & Company
B	1988 Motorola, Inc.

Exhibit 10: SPSS Variable Names

Quality Management Practices	
Variable	Survey Question
P1	Understanding corporate strategies
P2	Identifying/reviewing the strategic goals of R&D
P3	Identifying/ reviewing the purpose of R&D
P4	Reviewing existing R&D processes
P5	Copying successful R&D processes
P6	Establishing a quality management steering committee
P7	Implementing a R&D process improvement team
P8	Undertaking quality improvement projects
P9	Implementing formal systems of metrics
P10	Obtaining quality certification
P11	Conducting formal deliberation with senior managers
P12	Having senior management evaluate research projects
P13	Implementing exploration groups
P14	Determining the competitive position of R&D
P15	Identifying intellectual property
P16	Monitoring intellectual property
P17	Implementing common research databases
P18	Developing common research methodologies
P19	Documenting current practices
P20	Implementing effective reporting practices
P21	Providing employee awareness on quality issues
P22	Providing employee education on quality issues
P23	Involving employees in R&D decision making
P24	Monitoring the transfer of employees
P25	Ex-post evaluation of research
P26	Reviewing conformance to clients' requirements
P27	Partnering with clients to identify needs/requirements
P28	Establishing trust with clients
P29	Partnering with suppliers to identify needs/requirements
P30	Establishing trust with suppliers
Quality Management Tools – Usage	
Variable	Survey Question
T1U	Pareto Analysis
T2U	Structured Diagrams
T3U	Shewhart-Deming Cycle
T4U	Brainstorming
T5U	Competitors benchmarking
T6U	Formal design of experiments
T7U	Quality function deployment
T8U	Formal set of quality metrics
T9U	Formal quality objectives
T10U	Formal meetings between R&D and clients
T11U	Peer reviews
T12U	Formal meetings between R&D and suppliers
T13U	Client ratings
T14U	Client surveys
T15U	Quality audits
T16U	Quality certification
T17U	Risk analysis

T18U	Cost/benefit analysis
Quality Management Tools – Appropriateness	
Variable	Survey Question
T1A	Pareto Analysis
T2A	Structured Diagrams
T3A	Shewhart-Deming Cycle
T4A	Brainstorming
T5A	Competitors benchmarking
T6A	Formal design of experiments
T7A	Quality function deployment
T8A	Formal set of quality metrics
T9A	Formal quality objectives
T10A	Formal meetings between R&D and clients
T11A	Peer reviews
T12A	Formal meetings between R&D and suppliers
T13A	Client ratings
T14A	Client surveys
T15A	Quality audits
T16A	Quality certification
T17A	Risk analysis
T18A	Cost/benefit analysis
Quality Management Biases	
Variable	Survey Question
B1	Quality management practices restrict the creative requirements for successful research
B2	Scientists consider quality to be beneath them
B3	Quality management is just the latest fad of management
B4	Quality management focuses on efficiency and not effectiveness
B5	Quality management practices are quantitative based and are therefore not applicable to R&D
B6	Quality management practices focuses only on the quality of products/services
Other Practices, Tools, and Biases	
Variable	Survey Question
OP1 - OP5	Other quality management practices
OU1- OU5	Other quality management tools – Usage
OA1- OA5	Other quality management tools – Appropriateness
OB1- OB3	Other quality management biases.

Exhibit 11: Test for Outliers

Variable	N	Minimum	Maximum
P1	21	1.00	5.00
P2	21	1.00	5.00
P3	21	2.00	5.00
P4	21	2.00	5.00
P5	21	2.00	5.00
P6	21	1.00	5.00
P7	21	1.00	5.00
P8	21	2.00	5.00
P9	21	1.00	5.00
P10	21	1.00	5.00
P11	21	2.00	5.00
P12	21	1.00	5.00
P13	21	2.00	5.00
P14	21	2.00	5.00
P15	21	2.00	5.00
P16	21	1.00	5.00
P17	21	1.00	5.00
P18	21	1.00	5.00
P19	21	1.00	5.00
P20	21	3.00	5.00
P21	21	2.00	5.00
P22	21	3.00	5.00
P23	21	2.00	5.00
P24	21	1.00	5.00
P25	21	2.00	5.00
P26	21	2.00	5.00
P27	21	2.00	5.00
P28	21	2.00	5.00
P29	21	3.00	5.00
P30	21	2.00	5.00

Variable	N	Minimum	Maximum
T1U	21	1.00	5.00
T2U	21	1.00	5.00
T3U	18	1.00	5.00
T4U	21	2.00	5.00
T5U	21	2.00	5.00
T6U	21	1.00	5.00
T7U	21	1.00	5.00
T8U	21	1.00	5.00
T9U	21	2.00	5.00
T10U	21	2.00	5.00
T11U	21	2.00	5.00
T12U	21	1.00	5.00
T13U	21	1.00	5.00
T14U	21	1.00	5.00
T15U	21	1.00	5.00
T16U	21	1.00	5.00
T17U	21	1.00	5.00
T18U	21	1.00	5.00
T1A	20	2.00	5.00
T2A	21	2.00	5.00
T3A	17	1.00	5.00
T4A	21	2.00	5.00
T5A	21	1.00	5.00
T6A	21	1.00	5.00
T7A	20	1.00	5.00
T8A	21	1.00	5.00
T9A	21	2.00	5.00
T10A	21	2.00	5.00
T11A	21	3.00	5.00
T12A	21	2.00	5.00
T13A	20	1.00	5.00
T14A	20	1.00	5.00
T15A	20	1.00	5.00
T16A	20	1.00	5.00
T17A	20	1.00	5.00
T18A	20	1.00	5.00
B1	21	1.00	5.00
B2	21	1.00	4.00
B3	20	1.00	4.00
B4	21	1.00	4.00
B5	21	1.00	3.00
B6	21	1.00	5.00

Exhibit 12: Test for Skew and Kurtosis

Variable	N	Skewness		Kurtosis	
	Statistic	Statistic	Std. Error	Statistic	Std. Error
P1	21	-1.597	.501	1.585	.972
P2	21	-1.132	.501	.273	.972
P3	21	-.263	.501	-.692	.972
P4	21	-.263	.501	-.692	.972
P5	21	-.415	.501	-.450	.972
P6	21	-.151	.501	-.631	.972
P7	21	-.536	.501	.338	.972
P8	21	-.498	.501	-.950	.972
P9	21	-.559	.501	-.775	.972
P10	21	-.351	.501	-1.290	.972
P11	21	-.082	.501	-.474	.972
P12	21	-.065	.501	-.002	.972
P13	21	-.313	.501	-.215	.972
P14	21	-.207	.501	-1.120	.972
P15	21	-.324	.501	-1.021	.972
P16	21	-.909	.501	1.450	.972
P17	21	-.332	.501	-.184	.972
P18	21	-.065	.501	.214	.972
P19	21	-.823	.501	.488	.972
P20	21	.052	.501	-.498	.972
P21	21	-.996	.501	1.192	.972
P22	21	-.631	.501	-.765	.972
P23	21	-.996	.501	1.192	.972
P24	21	-1.327	.501	2.516	.972
P25	21	-.010	.501	-.467	.972
P26	21	-1.265	.501	2.297	.972
P27	21	-.996	.501	1.192	.972
P28	21	-2.148	.501	3.966	.972
P29	21	-.132	.501	-.764	.972
P30	21	-.921	.501	-.254	.972
T1U	21	.077	.501	-1.378	.972
T2U	21	.085	.501	-.320	.972
T3U	18	-.123	.536	-1.088	1.038
T4U	21	-1.364	.501	2.366	.972
T5U	21	-.190	.501	-.785	.972
T6U	21	-.466	.501	-.006	.972
T7U	21	.117	.501	-1.010	.972
T8U	21	-.522	.501	-.547	.972
T9U	21	-.663	.501	-.537	.972
T10U	21	-.789	.501	-.612	.972
T11U	21	-.190	.501	-.785	.972
T12U	21	-.204	.501	-.167	.972
T13U	21	.097	.501	-.890	.972
T14U	21	.398	.501	-.551	.972
T15U	21	-.256	.501	-1.103	.972
T16U	21	-.352	.501	-1.386	.972
T17U	21	-.516	.501	-1.048	.972
T18U	21	-.738	.501	-.740	.972

Variable	N	Skewness		Kurtosis	
	Statistic	Statistic	Std. Error	Statistic	Std. Error
T1A	20	.174	.512	-1.352	.992
T2A	21	.549	.501	-.245	.972
T3A	17	-.527	.550	-.658	1.063
T4A	21	-.902	.501	.322	.972
T5A	21	-.654	.501	-.286	.972
T6A	21	-1.291	.501	1.476	.972
T7A	20	-.204	.512	-.828	.992
T8A	21	-.571	.501	-.870	.972
T9A	21	-1.202	.501	.526	.972
T10A	21	-.902	.501	.322	.972
T11A	21	-.189	.501	-1.526	.972
T12A	21	.188	.501	-.749	.972
T13A	20	-.835	.512	.475	.992
T14A	20	-.400	.512	-.696	.992
T15A	20	-.697	.512	.602	.992
T16A	20	-.243	.512	-1.116	.992
T17A	20	-1.285	.512	2.227	.992
T18A	20	-.933	.512	.238	.992
B1	21	1.071	.501	1.119	.972
B2	21	.519	.501	-.868	.972
B3	20	1.036	.512	-.198	.992
B4	21	.065	.501	-1.329	.972
B5	21	.251	.501	-.645	.972
B6	21	1.326	.501	2.705	.972

Exhibit 13: Histogram of Significantly Skewed and Kurtopic Variables

P26

P26

P28

P28

T4U

T4U

T17A

T17A

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14.0 – APPENDICES

Appendix A: Comments from Respondents

There are different types of R&D and many manufacturing models are not appropriate for achieving quality in R&D.

Quality in R&D is a requirement.

Quality in R&D is beneficial and gain some but you must get through the BS to get to the meat.

Don't produce anything without a process for quality.

To achieve quality in R&D you must think in terms of business processes. This is the same in every business function. You must continue to improve upon these business practices and processes.

You must design quality into the product and process.

The factory floor concepts of quality do apply to R&D, but they must be tailored to work.

Quality must be designed in and not tested. There is always the view that there is time to do it over but never enough time to do it right.

The link to the Internet has resulted in getting data faster and easier. It allows for the sharing of information.

TQM is a cynical term. Quality is very important in any job.

There is a need to get away from the quality fads.

Quality in R&D is very important. It must be managed properly.

SEI does more or less the same. <Referring to applying quality management in R&D>

<Quality in R&D is> applicable but it is a hard thing to identify. <Quality in R&D> defies the statistical measures that are well defined. It is hard to make the cultural shift.

Quality in R&D is tough to obtain. Quality is a good thing. QS9000 has many documents and forms and is a quality hassle.