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www.emeraldinsight.com/0265-671X.htm

Received November 2004
Revised August 2005

Plant location, ISO 9000 certifications and quality management practices

An empirical investigation

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Abstract

Purpose – The main purpose of this study is to examine the impact of the country in which a manufacturing plant is located on its ability to achieve one or more of the ISO certifications, and the extent to which six other quality management practices have been implemented. It also examines the impact of achieving world class manufacturing status (WCM) on product quality. Product quality was measured by finished-product first-pass yield, scrap and rework costs, and warranty costs as percentages of sales.

Design/methodology/approach – The analyses are based on empirical data collected from more than 2900 manufacturing plants in the USA Canada, and Mexico.

Findings – The results show that there are significant differences in the plants' efforts to achieve quality certifications. Significant differences were also found in the extent to which six other quality management techniques are implemented. More important, our results show that there are significant differences in product quality performance among plants with different levels of progress toward achieving WCM status.

Originality/value – The findings of this study have many implications for both academic and practitioners who are interested in studying the impact of ISO 9000 and Quality Management practices.

Keywords Quality management, Six sigma, Total quality management, ISO 9000 series

Paper type Research paper

1. Introduction

The last two decades of the twentieth century have witnessed a new evolution and maturity of quality management practices, especially in the industrialized world.

Source of the data is *Industry Week*'s census of manufacturers (Copyright, Penton Media, Inc. 2001). The authors thank the *Industry Week*'s staff and executives who made this data available for them. The authors would like to acknowledge the support provided by King Fahd University of Petroleum and Minerals toward the completion of this research project.

International Journal of Quality & Reliability Management
Vol. 23 No. 8, 2006
pp. 944-963
© Emerald Group Publishing Limited
0265-671X
DOI 10.1108/02656710610688158

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Managing quality has quickly moved from quality control (QC) to quality assurance (QA) to total quality management (TOM); a progression in which new developments do not negate their predecessors, but rather build on them. Quality management practices and paradigms will continue to evolve in the twenty-first century. One of these new paradigm is quantum quality (QQ) (Miller, 1993). Although the seeds of this new paradigm shift were planted more than 10 years ago, it has not been operationalized or tested yet.

Youssef's (1992, 1993, 1994a, b, 1995) and Youssef *et al.*'s (1996, 2002) work on measuring the intensity of TQM and other time-based technologies such as group technology (GT), design for manufacturability (DFM), and just-in-time (JIT) is a step in this direction. In a nut shell, QQ will be based on continuous learning and organizational adaptability. Creating, managing, and sharing knowledge across the supply chain will be a critical success factor for this new paradigm. In addition, the principles of complex adaptive systems, especially the concepts of self-organization and managing the organization as if it was poised at the edge of chaos, will foster and promote an environment for the QQ mind-set. Because QQ paradigm has not been tested empirically, we alert the reader that this new paradigm and its practices will be tested in another paper.

The quality management literature is replete with studies that address quality management practices, not only in the Western hemisphere, but also in a host of countries around the globe. Studies by Flynn *et al.* (1994, 1995), Ahire *et al.* (1996), Black and Porter (1996), Samson and Terziovski (1999), Hongmeng *et al.* (2000), Marcos *et al.* (2000), Sun (2000), Kuei *et al.* (2001), Park *et al.* (2001) and Chin *et al.* (2002), represent examples. An extensive search in the ABI Inform database using the term "quality management practices/techniques," resulted in more than 2,500 articles that have a combination of these words in the title, abstract, or body of the text. Using other search terms such as QC, TQM or its abbreviation TQM, ISO 9000, quality management tools such as SPC and SQC, our search produced thousands of articles. Taking into consideration the number of doctoral dissertations and master theses written on the subject, one can easily say that quality management is one of the most talked about topics in the history operations and quality management literature.

Notwithstanding this bulk of articles, there is an urgent need for more practical definitions of some or all of these practices/techniques and their classifications. Existing definitions and classification are divergent to the extent that some researchers refer to quality management practices in different ways. Some authors refer to these practices as "techniques," "factors," "principles," or even "guidelines". In addition, existing classification of quality management practices are influenced mainly by quality awards frameworks and guidelines such as those of the Malcolm Baldrige National Quality Awards (MBNQA) and/or the European Model for quality management.

The seminal work by Saraph *et al.* (1989) on quality management practices paved the way for more empirical research on quality management practices and their relationship to business performance. Since that seminal work, a number of studies have examined different facets of quality management practices (Flynn *et al.*, 1994, 1995; Dow *et al.*, 1999; Ahire *et al.*, 1996; Douglas and Judge, 2001; Samson and Terziovski, 1999). The common thread that ties these studies together is that they

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utilize the MBNQA framework to classify quality management practices. We will examine these and other related studies in the literature review segment of this paper.

This paper makes a unique contribution to the existing body of quality management literature in that it addresses quality management practices from a different perspective and emphasizes a number of important issues. First, it examines the efforts of more than 2,900 manufacturing plants towards achieving one or more of the international quality certifications such as ISO 9000, QS 9000, and ISO 14000. It also examines the extent to which six sigma, TQM, statistical process control (SPC), error proofing techniques (Poka Yoke), continuous improvement programs, and process capability measures have been implemented. More important, it examines how the progress toward achieving WCM status affects finished-product first-pass yield, scrap and rework cost as a percentage of sales, and warranty costs as a percentage of sales.

The remainder of this paper is organized as follows. In Section 2, relevant quality management practices literature is carefully examined to establish the legitimacy of our research questions. Owing to the fact that quality management literature is pervasive, we limited our review to studies relevant to the subject of this paper. In Section 3 we state the research questions and hypotheses. Section 4 is about the research methodology and statistical methods. In Section 5, we present the analyses used in testing the research hypotheses. The final section of the paper draws some conclusions and makes suggestions for future work relating to quality management practices in North America.

2. Relevant literature

In this part of the paper, we review the relevant and most recent literature on quality management practices and quality performance. However, we need to define the term "quality management practices."

2.1 Quality management practices defined

In our attempt to define quality management practices, we borrow from the management and organizational theory literature, specifically the paper by Zeitz *et al.* (1999), in which relevant and interrelated terms such as adoption, fad, and entrenchment were defined. According to Zeitz *et al.* (1999), adoption of a practice refers to "Its selection and initial use by an organization or one of its sub-units that has not used it previously." A fad is defined as "specific practice that has been adopted, but which lacks entrenchment." Finally, entrenchment refers to "the presence of a practice within an organization such that abandonment of it is unlikely, even under extreme pressure." Dale *et al.* (2002) addressed the question of how learning and changes in organizational process can be retained within the organization so that they actually buildup over time and eventually make the organization ripe for major improvement change.

We, therefore, define quality management practices as those:

> " quality techniques" and "behaviors" entrenched within an organization or its sub-units under two conditions. First, these techniques and behavior are in congruent with criteria established by International Standardization Organization or they are embodied in a framework of a national or an international quality award frameworks such as those of the Malcolm Baldrige National Quality Award (MBNQA) or the European Foundations of

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Quality Management (EFQM). Second, these techniques must help the organization or its sub-units achieve a sustainable competitive advantage at both operational and strategic levels – that is they impact the business performance of an organization or one or more of it sub-units.

Our definition is distinctive in many respects. First, the set of criteria established by an accreditation body, or those criteria embedded in a quality award framework, are universal in nature. Their use in classifying quality management practices will minimize the disagreement among academics and practitioners on this critical issue. Second, a careful examination of most of the empirical research on quality management practices has shown that most of these studies were based on the MBNQA framework. Third, a quality management practices must be entrenched in an organization and should not be regarded as just a fad. Finally, proper implementation of these quality management practices should enhance an organization's sustainable competitive advantage.

2.2 Classification of quality management practices in prior literature

Before we attempt to classify quality management practices, it is important to mention that the list of practices depicted in Table I is not, by any means, collectively exhaustive. In our literature review, we opted to place an emphasis on the prior literature that is directly relevant to this study. Looking at the table from chronological perspective, one may observe that in any of the selected years there may be other studies on the same subject. However, as we indicated earlier, we considered only those that are related to the subject of this paper. The absence of other studies in our literature review does not undermine their importance or usefulness.

It is clear from this summary of the literature review that there are divergent perspectives on what constitutes quality management practices. However, common to most of these studies, are factors such as customer focus, quality leadership, supplier involvement, and more importantly, human resource management practices such as empowerment, involvement, training and education. These common factors are rooted in the contribution of the quality management gurus and in the landmark empirical studies by Saraph *et al.* (1989), Flynn *et al.* (1994, 1995), Dow *et al.* (1999), Powell (1995), Ahire *et al.* (1996) and Samson and Terziovski (1999).

2.3 World class manufacturing defined

According to Giffi *et al.* (1990), the term world-class manufacturing was coined by Hayes and Wheelwright in early 1980s. It was explicitly used in the writings of Schonberger (1986), Gunn (1987), Hayes *et al.* (1988), Giffi *et al.* (1990) and Paddock (1993), just to mention a few. It is our belief that the work of Richard Schonberger in 1986 has accelerated the awareness of this new manufacturing philosophy. Since the publication of his book "World Class Manufacturing: The lessons of simplicity applied," there have been a plethora of writings that have attempted to define or operationalize the term WCM. According to Schonberger (1986) the term WCM captures the "breadth and essence of fundamental changes taking place in larger industrial enterprises."

According to Gunn (1987), there are three criteria upon which we can judge whether a company is a world-class manufacturer. These are WIP inventory turns, the level of quality, and manufacturing. The first of these three criteria is work-in-process (WIP)

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Table I.
Relevant literature on quality management practices

Author(s)	Quality management practices
Saraph *et al.* (1989)	Top management leadership
	Quality and data reporting
	Process management
	Product/services
	Design
	Training
	Supplier quality management
	Role of the quality department
	Employee relation
Flynn *et al.* (1994)	Top management support
	Quality information'
	Process flow management
	Product design
	Workforce management
	Supplier involvement
	Customer involvement
Flynn *et al.* (1995)	Top management support
	Process control
	Employee involvement
	New product quality
	Concurrent engineering
	SPC/feedback
	Maintenance
Powell (1995)	Executive commitment
	Measurement
	Zero defect mentality
	Process improvement
	Training
	Closer to supplier
	Employee involvement
	Open organization
	Flexible manufacturing
	Closer to customer
	Benchmarking
Sjoblom (1995)	Structured quality systems
	Statistical techniques
	Quality management leadership
Ahire *et al.* (1996)	Top management commitment
	Internal quality and information usage
	Design quality management
	Employee training
	Supplier quality management
	Employee involvement
	Employee empowerment
	Employee training
	Customer focus
	SPC usage
	Benchmarking
Black and Porter (1996)	Strategic quality management
	Quality improvement measurement

(*continued*)

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Author(s)	Quality management practices
	Communication
	Operational quality planning
	External interface management
	Supplier partnership
	People and customer management
	Customer satisfaction orientation
Choi and Eboch (1998)	HRM practices
	Process quality
	Information and analysis
	Performance
Choi and Rungtusantatham (1999)	Management of process quality
	Human resource development and management
	Strategic quality planning
	Information and analysis
Samson and Terziovski (1999)	Leadership
	HRM practices
	Customer focus
	Use of information and analysis
	Process improvement
	Strategic and quality planning
Dow *et al.* (1999)	Workforce commitment
	Shared vision
	Use of teams
	Personnel training
	Customer focus
	Co-operative supplier relationships
	Use of benchmarking
	Use of advanced manufacturing systems
	Use of JIT principle
Abdul-Aziz *et al.* (2000)	Goods in
	Manufacturing
	Goods out
	Design
	Employees
Agus and Abdullah (2000)	TQM
	QCC
	Kaizen
	JIT
	Kanban
	Others
Hongmeng *et al.* (2000)	Leadership
	Processes
	Policy and strategy
	People management
	Employee involvement
	Quality assurance
	Supplier quality
	Customer satisfaction
	Impact on society

(continued)

Table I.

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Author(s)	Quality management practices
Douglas and Judge (2001)	Top management involvement
	Adoption of quality philosophy
	Emphasis on TQM-oriented training
	Focus on the customer
	Continuous improvement of processes
	Management by fact
	Use of TQM methods
Motwani (2001)	Top management commitment
	Quality measurement and benchmarking
	Process management
	Product design
	Employee training and empowerment
	Vendor quality management
	Customer involvement and satisfaction
Park *et al.* (2001)	Information management
	Strategic planning
	Employee satisfaction
	Empowerment
	Employee education and development
	Process management
	Supply management

Table I.

inventory turns. Gunn (1987) classifies world-class manufacturers into three classes. A company that can turn WIP 25-30 times is a class C world-class manufacturer. If the number of inventory turns goes up to 50-60 turns, Gunn (1987) views this type of companies as class B world-class manufacturer. Finally, if a company can raise its inventory turn to 80-100 turns per year, then this company can be classified as class A world-class manufacturer..

The second criterion necessary for the achieving a WCM status is the level of quality. Gunn (1987) argues, and rightly so, that a world class manufacturer should have fewer than 200 defective parts per million of any product it manufactures. Recently, the POM literature shows that many of the companies that have achieved WCM status are embracing and implementing the six-sigma philosophy. The third criterion, according to Gunn (1987) is manufacturing cycle time. He considers the reduction in cycle time as a necessary, but might not be sufficient, criterion for achieving the WCM status.

2.4 Quality management practices and business performance

The TQM literature, especially in the past two decades of the twentieth century, is replete with empirical studies that examine the impact of TQM on financial performance. See, for example, studies by Hendricks and Singhal (1997), Terziovsky and Samson (1999), Dow *et al.* (1999), Hongmeng *et al.* (2000) and Abdul-Aziz *et al.* (2000).

Hendricks and Singhal (2001) examined the relationship between changes in operating income associated with the effective implementation of TQM to various firm characteristics such as size, degree of capital intensity, the degree of

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diversification, timing of TQM implementation and the maturity of the quality management program. Three important findings emerged from this study. First, less capital-intensive firms were found do better than more capital-intensive firms. Second, firms that are more focused do better than more diversified firms. Finally, time since implementing TQM was found to have no impact on performance, since no significant differences in performance between of earlier and later implementers of effective TQM were found.

Terziovsky and Samson (1999) studied the link between TQM practices and operational performance in more than 1,300 manufacturing companies in Australia and New Zeeland. They tested the strength of the relationship between TQM practices and operational performance with and without covariates such as company size, industry type, and ISO 9000 certification status. Their analysis shows that TQM is significantly related to variety of performance measures. However, TQM tend to exhibit mixed results when co-varied with company size and industry type, though not with the ISO 9000 certification status. This interesting finding is congruent with many academics and practitioners' view that unless the implementation of ISO 9000 becomes an integrated part of the TQM philosophy, it will have little or no explanatory power of organizational performance.

Using a sample of 1,289 manufacturing sites, Dow *et al.* (1999) examined the dimensions of quality management practices, and their impact on quality outcomes. Their rigorous analysis results in interesting findings. First, from a list of 44 quality management practices, they extracted nine quality management dimensions – workforce commitment, shared vision, use of teams, personnel training, customer focus, co-operative supplier relationships, use of benchmarking, use of advanced manufacturing systems, and use of JIT principle. Second, they examined the relationship between quality management practices and quality outcome. Third, parallel to the study by Dow *et al.* (1999) found that only three of the nine practices have a strong relationship with quality outcome.

Hongmeng *et al.* (2000) studied quality management practices and their impact on business performance in Shanghai manufacturing industries. Their findings indicate that companies that implemented quality practices have better business results, including higher market share, higher profitability and lower costs. Surprisingly, companies that registered for ISO 9000 did not obtain better quality management practices and results than those that had not yet registered. They also found that the time length of quality management implementation is not related to TQM practices and results. This finding is not supported by similar studies. For example, Youssef *et al.* (1996) found that time since implementation is positively correlated with business performance.

Abdul-Aziz *et al.* (2000) compared quality practices in manufacturing industries in the UK and Malaysia. They classified 37 quality management practices into five quality management dimensions- goods in (6 practices), manufacturing (7 practices), goods out (3 practices), design (7 practices), and employees (14 practices). The results of their analysis showed some similarities and differences in quality management practices between the two countries. One of the most noticeable similarities is the use of sampling inspection. Among differences were: the use of ISO 9000, the use of written procedures, and design.

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What relevance do these studies have for our research? First, there is no doubt that quality management practices can impact the business performance of a company. However, the direction and magnitude of such impact are functions of the company's effort to create the proper environment for entrenching these practices in their manufacturing organizations. Second time since the implementation of some or all of the quality management practices can be equally important. It is of the utmost importance that the management of a manufacturing organization adopt a long-term perspective if they are to harvest the results of entrenching quality management practices. By adopting a short-term strategy as to the expected benefits that may be gained from proper implementation of quality management practices, the management of the manufacturing organization will not only be "shooting themselves in the foot," but also weeding their companies out of the market. Third, efforts to achieve world class manufacturing status (WCM) affect product quality as well as the time-based performance of the manufacturing organization. This issue of examining quality performance in conjunction with achieving WCM status deserves more attention, at least empirically. This paper is a step in this direction. Our research questions and hypotheses are state below.

3. Research questions and hypotheses

One of the main objectives of this study is to investigate whether manufacturing plants operating in the USA, Canada, and Mexico differ in their efforts to achieve one or more of the quality certifications such as ISO 9000, ISO 14000, and QS 9000. We opted to study manufacturing plants in Canada, Mexico, and the USA, for they are the most industrialized countries in North America. Additionally, plants' manufacturing strategies in these three countries are supposed to be comparable. Owing to the exploratory nature of this study, our *H1* reads:

> H_0. No significant differences in achieving quality certifications among manufacturing plants operating in the three countries.

Another objective of this study was to investigate if there are significant differences in the extend to which six sigma, TQM, formal continuous improvement programs, process capability measures, error proofing, and SPC are implemented in the three countries. Our *H2*, therefore, reads:

> H_0. No significant differences among manufacturing plants operating in North America in the extend to which one or more of the six quality management techniques have been implemented.

A third objective of this study is to investigate differences in quality performance variables among manufacturing plants with different level of progress toward achieving world-class manufacturing status. Quality performance variables include: percentage of finished-product first-pass quality yield, plant's scrap and rework costs as a percentage of sales, and plant's warranty costs (repair and replacement) as a percentage of sales. We, therefore, hypothesize that:

> H_0. No significant differences in quality performance variables among manufacturing plants with different levels of progress toward achieving world-class manufacturing status.

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4. The research methodology

This paper uses data collected through a mailed questionnaire survey as part of the *Industry Week*/Pricewaterhouse manufacturing census database. The census manufacturing survey has been conducted for a number of years. Starting in 1999, the survey was administered in Canada, Australia, and Mexico. In this paper, we use the data collected in 2001 from USA, Canada, and Mexico as the three most industrialized nations in North America.

4.1 Operationalization of variables

4.1.1 Quality certificates. Respondents were asked to indicate which of the following quality certificates their plant had received: ISO 9000, QS 9000, ISO 1400. Each of these variables was operationalized as a zero-one variable, where one signifies the achievement of this quality certification, and zero indicates otherwise. These variables were the dependent variables in *H1*. The independent variable is the country in which the manufacturing plant operates.

4.1.2 Quality techniques implementation. Respondents were asked about the extent to which six sigma, TQM, formal continuous improvement program, process capability measures, error proofing, and SPC have been implemented. These variables were operationalized on a continuum that ranged from no implementation to extensive implementation. Each response provided a dependent variable in the *H2*. Once again, the independent variable was the country in which the manufacturing plant operates.

4.1.3 Quality performance variables. Respondents were asked about the approximate percentage of finished-product first-pass quality yield, plant's scrap and rework costs as a percentage of sales, and plants warranty costs as a percentage of sales. These three variables were operationalzed as continuous variables, with respondents reporting the percentages. The three variables were the dependent variables in the *H3*. The independent variable was the manufacturing plant's effort to achieve WCM status.

5. Analyses

The statistical analyses in this paper were conducted in two stages. First, we discuss some key variables and profile of respondents in terms of workforce unionization, the progress toward achieving world-class manufacturing status, time since plant startup (age of the plant), and the size of the plants as measured by number of employees. In the second stage of the analysis, we utilized multivariate statistical techniques such as MANOVA, MANCOVA, one-way ANOVA, and multiple comparison procedures to test the three hypotheses. The analysis strategy is pictorially shown in Figure 1.

5.1 Profile of the respondents

This part of the analysis includes variables such as work force unionization, progress toward achieving WCM status, time since startup, and size of the plant as measures by number of employees. Tables II-V project frequency analysis for each of these variables.

5.1.1 Workforce unionization. Respondents were asked about the extent to which the plant workers are represented by unions. Table II shows that almost 65 percent of the workers were not unionized. Why examine this variable, one might ask? Manufacturing management literature in the early 1980s revealed moderate to strong

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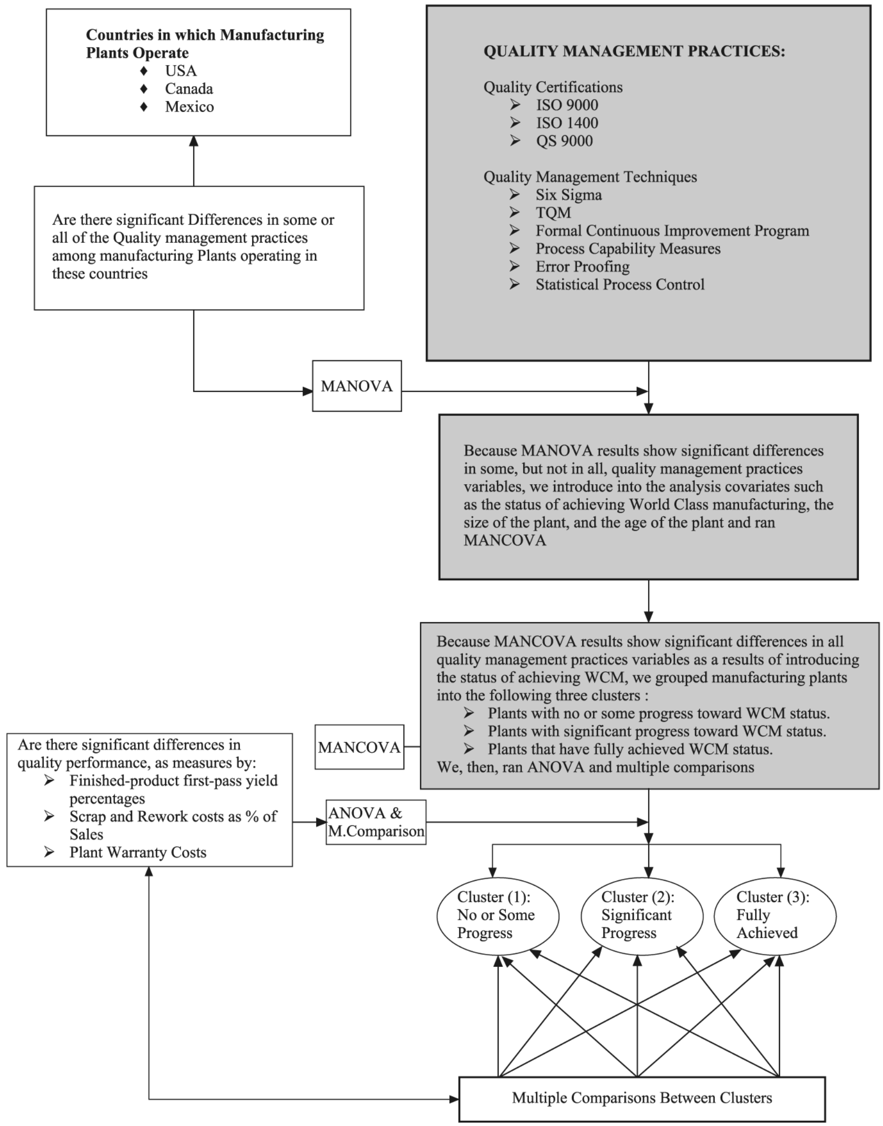

Figure 1.
Analysis strategy

correlation between the level of unionization and manufacturing performance. In essence, less unionized factories are expected to be more productive than unionized ones. Although not examined here, the statistics in Table II shows a tendency toward a less unionized factory.

5.1.2 Progress toward WCM status. Respondents were asked to indicate how much progress has been made toward achieving WCM status. This variable was operationlized on a continuum that ranges from “no progress” to “fully achieved.” Table III shows that only 4.5 percent of the sample had achieved world-class

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manufacturing status. This was a somewhat surprising result in that WCM has been around for almost two decades, yet it is apparent that the efforts of manufacturing plants have not been great.

Data collected from the same industries in four consecutive years (1997-2001) showed that the percentage of plants that achieved WCM status was between 4.0 and

Table II. To what extent are plant production workers represented by a union(s)?

		Frequency	Percentage	Valid percentage	Cumulative percentage
Valid	No workers	1,877	64.5	64.8	64.8
	Some workers	280	9.6	9.7	74.5
	All workers	738	25.4	25.5	100.0
	Total	2,895	99.6	100.0	
Missing	System	13	0.4		
Total		2,908	100.0		

Table III. Progress toward achieving world-class manufacturing status

		Frequency	Percentage	Valid percentage	Cumulative percentage
Valid	1. No or some progress	1,699	58.4	59.3	59.3
	2. Significant progress	1,035	35.6	36.1	95.4
	3. Fully achieved	131	4.5	*4.6*	100.0
	Total	2,865	98.5	100.0	
Missing	System	43	1.5		
Total		2,908	100.0		

Table IV. How many years has it been since plant start up?

		Frequency	Percentage	Valid percentage	Cumulative percentage
Valid	<5 years	126	4.3	4.4	4.4
	5-10 years	247	8.5	8.6	13.0
	11-20 years	565	19.4	19.7	32.8
	>20 years	1,925	66.2	*67.2*	100.0
	Total	2,863	98.5	100.0	
Missing	System	45	1.5		
Total		2,908	100.0		

Table V. How many employees are at this plant location?

		Frequency	Percentage	Valid percentage	Cumulative percentage
Valid	<100	404	13.9	15.7	15.7
	100-249	1,199	41.2	46.7	62.4
	250-499	539	18.5	21.0	83.3
	500-999	241	8.3	9.4	92.7
	1,000 or more	187	6.4	7.3	100.0
	Total	2,570	88.4	100.0	
Missing	System	338	11.6		
Total		2,908	100.0		

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6 percent. It is a surprising finding, especially when coupled with the age of participating plants and time since WCM philosophy emerged.

5.1.3 Plant age (time since start-up). Respondents were asked to specify the length of time since plant startup. Table IV shows that more than two-third of the sample were 20 years or older. This piece of information, coupled with the plant's progress toward world-class manufacturing and the fact that world-class manufacturing philosophy has been around for almost two decades, raises a host of questions about manufacturing competitiveness and productivity in North America.

5.1.4 Size of the plant (as measured by number of employees). Respondents were asked about the number of employees in their plants. Table V shows that more than 83 percent of the surveyed plants can be considered as small- to medium-size enterprises (SME's) by the Small Business Administration's definition. Only 17 percent of the responding plants had more than one thousand employees. This richness of diversified data allows for a comparative study of the quality management practices and performance in small versus large plants in North America.

5.2 Multivariate analysis of variance and covariance (MANOVA and ANCOVA)

The purpose of multivariate tests of significance is to assess the differences in dependent variables collectively rather than singularly (Hair *et al.*, 1998). Multivariate analysis of variance (MANOVA) was used to test the first two hypotheses. The dependent variables are the attainment of quality certifications (ISO 9000, ISO 14000, and QS 9000) and the extent to which each of the six quality management techniques was implemented. The independent variable is the country in which the manufacturing plant operates. No other covariates were used at this point in this stage of the analysis

The results of Pillai's Trace ($F = 6.418$, $P < 0.0001$), Wilks' λ ($F = 6.432$, $P < 0.0001$), Hotelling's Trace ($F = 6.446$, $P < 0.0001$), and Roy's Largest ($F = 9.537$, $P < 0.0001$) indicate that using any of these four tests of multivariate differences confirms that the combined dependent variables varied across the three countries in which manufacturing plants operated. Table VI shows these results.

Univariate F-tests show that there were no significant differences in attaining ISO 9000 ($F = 0.809$, $P = 0.445$) or QS 9000 ($F = 0.922$, $P = 0.398$). However, significant differences were found in attaining ISO 14000 ($F = 9.056$, $P < 0.001$).

As to the extent to which quality management practices were implemented, no significant differences were found in the degree of implementing six sigma or formal

Effect		Value	F	Hypothesis df	Error df	Sig.
Intercept	Pillai's Trace	0.749	819.877[a]	9.000	2,476.000	0.000
	Wilks' λ	0.251	819.877[a]	9.000	2,476.000	0.000
	Hotelling's Trace	2.980	819.877[a]	9.000	2,476.000	0.000
	Roy's Largest Root	2.980	819.877[a]	9.000	2,476.000	0.000
Country	Pillai's Trace	0.046	6.418	18.000	4,954.000	0.000
	Wilks' Lambda	0.955	6.432[a]	18.000	4,952.000	0.000
	Hotelling's Trace	0.047	6.446	18.000	4,950.000	0.000
	Roy's Largest Root	0.035	9.537[b]	9.000	2,477.000	0.000

Notes: [a]Exact statistic; [b]the statistic is an upper bound on F that yields a lower bound on the significance level; [c]design: intercept + country

Table VI. Multivariate tests[c]

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continuous improvement programs, at least at a significant level of ($P = 0.05$). The F-statistics and the P-values for these two variables were ($F = 2.66$, $P = 0.070$) and ($F = 2.631$, $P = 0.072$), respectively. However, significant differences were found in the extent to which TQM ($F = 5.128$, $P < 0.006$), process capability measurements ($F = 10.574$, $P < 0.001$), error proofing ($F = 24.112$, $P < 0.001$), and SPC ($F = 14.380$, $P < 0.001$) have been implemented

5.3 Introducing key co-variates

When the age of the manufacturing plant was introduced as a covariate, significant differences were found only in attaining QS 9000 ($F = 7.895$, $P < 0.005$) and the extent to which error proofing techniques have been implemented ($F = 10.026$, $P < 0.002$). No significant differences were found in the remaining seven dependent variables. Plant age, therefore, is not a good discriminator in either the plant's efforts to achieve quality certification or in the extent to which quality management practices have been implemented, at least in this sample.

When the progress toward achieving WCM status was introduced into the analysis, as another covariate, significant differences were found in all of the nine dependent variables ($P < 0.0001$ for all variables). This finding indicates that progress toward achieving WCM status is a good discriminator in the plant's efforts to achieve quality certification and in the implementation of the quality management techniques. These results motivated us to take the analysis one step further and examine the impact of the progress toward achieving WCM status on quality performance (*H3*).

5.4 Quality performance and WCM status

One of the main objectives of this paper was to examine the impact of the progress toward achieving WCM status on quality variables. To test this hypothesis, we grouped manufacturing plants in three groups, based on their progress toward achieving that status. The first group is manufacturing plants with no or some progress toward achieving WCM status ($n = 1669$). The second group is manufacturing plants with significant progress toward achieving that status ($n = 1{,}035$). The third group is manufacturing plants that have a fully achieved WCM status ($n = 131$).

To test our *H3*, we resorted to one-way analysis of variance (ANOVA) and Scheffe's multiple comparison procedure. The dependent variables here were quality performance as measured by the approximate finished-product first-pass yield, scrap and rework costs as a percentage of sales, and warrant costs as a percentage of sales. The independent variable was the progress toward achieving WCM status. The results of one-way ANOVA, descriptive statistics, and Scheffe's multiple comparison procedures are depicted in Tables VII, VIII, and IX, respectively.

Table VII shows that significant differences in the three quality performance variables existed among manufacturing plants with different levels of progress toward achieving WCM status.

Table VIII shows that manufacturing plants with a fully achieved WCM status had superior quality and cost performance. In fact this group of the manufacturing plants outperformed the other two groups on all three quality performance variables. The implication of these findings is that WCM plants can indeed achieve multiple

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Table VII.
One way analysis of variance

		Sum of squares	Df	Mean square	F	Sig.
13. What is the approximate finished-product first-pass quality yield for primary products?	Between groups	50.805	2	25.402	11.673	*0.000*
	Within groups	5,381.680	2,473	2.176		
	Total	5,432.485	2,475			
14. Approximately what are the plants scrap and rework costs as a percentage of sales?	Between groups	15.261	2	7.631	5.852	*0.003*
	Within groups	3,061.612	2,348	1.304		
	Total	3,076.874	2,350			
15. Approximately what are the plant's warranty costs (repair and replacement) as: percentage of sales?	Between groups	19.951	2	9.975	4.123	*0.016*
	Within groups	5,122.422	2,117	2.420		
	Total	5,142.373	2,119			

Table VIII.
Descriptive statistics of the quality performance variables

	Group1 (no or some progress toward WCM ($n = 1{,}699$)	Significant progress toward WCM ($n = 1{,}035$)	Fully achieved WCM status ($n = 131$)
13. What is the approximate finished-product first-pass quality yield for primary products?	3.8115* (*1.47060*)**	4.0471 (*1.49009*)	4.3462 (*1.40574*)
14. Approximately what are the plants scrap and rework costs as a percentage of sales?	2.8115 (*1.15245*)	2.6465 (*1.13292*)	2.6563 (*1.06453*)
15. Approximately what are the plant's warranty costs (repair and replacement) as a percentage of sales?	3.2027 (*1.55348*)	3.0119 (*1.57021*)	2.9545 (*1.45357*)

Notes: *Mean; **standard deviation

competitive advantages in terms of cost and quality. This finding does not support the notion of a trade-off between cost and quality.

5.4.1 Multiple comparisons. For the finished-product first-pass yield, Scheffe's multiple comparison procedure showed that there were significant differences between manufacturing plants with no or some progress toward achieving WCM status and manufacturing plants with significant progress toward WCM status. There were also significant differences between manufacturing plants with no or some progress and

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Scheffe Dependent variable	(*I*) q2nthree	(*J*) q2nthree	Mean difference (*I* − *J*)	Std. Error	Sig.
13. What is the approximate finished-product first-pass quality yield for primary products?	1. No or some progress	2	−0.23558*	0.06225	*0.001*
		3	−0.53464*	0.14972	*0.002*
	2. Significant progress	1	0.23558*	0.06225	*0.001*
		3	−0.29906	0.15267	0.147
	3. Fully achieved	1	0.53464*	0.14972	*0.002*
		2	0.29906	0.15267	0.147
14. Approximately what are the plants scrap and rework costs as a percentage of sales?	1. No or some progress	2	0.16496*	0.04951	*0.004*
		3	0.15522	0.12049	0.436
	2. Significant progress	1	−0.16496*	0.04951	*0.004*
		3	−0.00974	0.12288	0.997
	3. Fully achieved	1	−0.15522	0.12049	0.436
		2	0.00974	0.12288	0.997
15. Approximately what are the plant's warranty costs (repair and replacement) as a percentage of sales?	1. No or some progress	2	0.19081*	0.07134	0.028
		3	0.24813	0.17146	0.351
	2. Significant progress	1	−0.19081*	0.07134	0.028
		3	0.05731	0.17517	0.948
	3. Fully achieved	1	−0.24813	0.17146	0.351
		2	−0.05731	0.17517	0.948

Note: *The mean difference is significant at the 0.05 level.

Table IX.
Multiple comparisons

manufacturing plants that have a fully achieved WCM status. For scrap and rework costs, as well as warranty costs, significant differences only exist between manufacturing plants with no or some progress and those with significant progress toward WCM status. These results are depicted in Table IX.

6. Conclusion

The subject of quality management practices and their impact on business performance has been addressed frequently in the past two decades. Most of the empirical studies found in quality management literature built their classification of quality management practices on the MBNQA's framework. However, there have been divergent views in defining and classifying these practices. This paper's contribution to the existing literature is noticeable by the fact that it attempts to define and classify quality management practices differently. Our rationale for doing so is motivated by the lack of a universal method for defining and classifying quality management practices.

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The analysis in this paper was based on data collected from 2,908 manufacturing plants operating in three countries in North America. Our analyses show the existence of significant difference in the manufacturing plant's efforts to achieve ISO 9000 and QS 9000. Manufacturing plants operating in the three countries in North America differ in their efforts to attain ISO 14000. These findings indicate that some of the three countries give more attention to environmental issues related to quality. This is obvious in the case of the USA and Canada

The extent to which the six quality management techniques were implemented in manufacturing plants operating in the three countries differed significantly, especially when covariates such as the progress toward achieving WCM status were introduced into the analysis. The age of the plant was not a good discriminator in the implementation of quality management techniques or in the quality performance.

The analysis of plants' efforts toward achieving WCM status and quality management performance produced several interesting findings. Plants with a fully achieved WCM status have superior quality and lower costs. The implication of this finding is that multiple competitive advantages can be achieved.

Among surprising results were that the percentage of manufacturing plants in the three countries who have fully achieved WCM status is very small. Only 3.3 percent of the 2,809 respondent achieved that status. The fact that WCM philosophy has been around for at least two decades, and more than 75 percent of the plants are twenty years or older, raises more serious questions about the productivity and competitiveness of manufacturing plants operating in these three countries. A longitudinal analysis of these phenomena may enable us to answer questions such as "why did North American manufacturers lose their competitive advantages in most industries, and what should they do to retain their lead in global markets?" Further, investigations are needed to address these and other related questions.

Our findings have several implications for both academics and practitioners. For academics the issue of time-based performance of world class manufacturers must be revisited in light of new developments such as lean manufacturing, six sigma. New developments in complexity and chaos theories, especially the concepts self organization, managing at the "edge of chaos," should guide researchers to develop appropriate methodologies to study the next generation manufacturing plants. Another area for further research is the operationalization and testing of the QQ paradigm. Although QQ paradigm has existed for more than 10 years, there is a serious need for testing its impact on business and organizational performance. For practitioners, the take home message is that accelerating the progress toward achieving WCM status will enhance the plant's quality and time-based performance, help companies achieve multiple competitive advantages, and pave the way for the extended enterprise.

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