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An Empirical Model for Managing Quality in the Electronics Industry

Andy C. L. Yeung • T. C. Edwin Cheng • Kee-hung Lai
Department of Logistics, The Hong Kong Polytechnic University, Hung Hom, Kowloon, Hong Kong
lgtandyy@inet.polyu.edu.hk • lgtcheng@polyu.edu.hk • lgtmlai@polyu.edu.hk

Much of the empirical research in the past two decades has suggested that quality management (QM) is context dependent. This research develops an empirical QM model in a technology-based sector—electronics manufacturing. Based on quantitative and qualitative investigations of 225 electronics firms in Hong Kong and the Pearl River Delta (PRD) region of China, a path analytic model is developed. The empirical model shows that a typical quality management system (QMS) in the electronics industry is composed of four major modules, namely leadership, cultural elements, operational support systems, and process management. These modules create a series of chain effects on organizational performance, rather than acting as parallel elements with an equal impact. By quantifying their effects on organizational performance and comparing the model to others in the literature, we identify those QM constructs that are context dependent. In electronics manufacturing, process management and customer focus are more important than other elements (e.g., cultural factors) for garnering business results. This study contributes to contingency theory and research by identifying the key constructs and their relationships in a competitive, volatile, and technology-based industry with complex supply networks.

Key words: quality management models; electronics industry; organizational performance; empirical research
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1. Introduction

Traditionally, theories of quality management (QM) were developed regardless of the type of operating environment, industry or technology involved (Crosby 1979; Juran 1986). At the organizational level of analysis, the configuration theory typically posits that organizations that resemble one of the ideal patterns or types of management systems defined in the general theory are more effective than other organizations (Doty, Glick, and Huber 1993). In contrast, a contextual view of the contingency theory prescribes that an organization must be aligned with its operating environment to achieve superior performance. The organization interacts with external factors to configure and match its internal resources to exogenous requirements. The system-structural view (Benson, Saraph, and Schroeder 1991) of QM states that the executive's basic role is to fine-tune the organization according to the exigencies that confront it, not to develop a standard set of "best practices." The universal orientation of QM has been pointed out as being in conflict with the contingent approach of management theory in general (Sousa and Voss 2001).

There is a growing body of research on the contingency theory of quality management. In the past decade, researchers have empirically investigated how the relationships between QM practices and organizational performance differ in various cultural settings (Rungtusanatham, Forza, Filippini, and Anderson 1998; Madu, Kuei, and Liu 1995), under a highly competitive environment (Das, Handfield, Calantone, and Ghosh 2000) and according to other contextual factors (e.g., Benson, Saraph and Schroeder 1991; Shah and Ward 2003). Some researchers have also explored how the relationships between QM practices and organizational performance are contingent on industry type (Kontoghiorghes 2003; Yang, Chen, and Su 2003). For example, Sharma and Gadenne (2002) revealed that QM practices appear to be more positively associated with objective performance measures (e.g., return on assets) in the service industry than in the manufacturing industry, and that QM practices seem to have little association with any performance measures in the construction industry. Lai and Cheng (2003) showed that differences in quality initiatives by industry type affect the levels of implementation of quality management and quality outcomes. As a whole, the studies have suggested that quality management tends to have mixed results when covaried with industry type (Samson and Terziovski 1999).

There is another stream of research focusing on the development of comprehensive models of quality management (e.g., Flynn, Schroeder, and Sakakibara 1995; Wilson and Collier 2000) and examining the models empirically in various industrial settings. This type of study depicts the inter-relationships among QM practices in helping firms to gain competitive advantages and in providing them with an important understanding of quality management in various organizational contexts. Although some empirical models of quality have been presented in the literature, very few of them are related to the high-technology sector. High-technology industries generally operate in a dynamic and competitive environment, producing complex products that require a firm to possess certain specialized knowledge and skills. In the technology sector, technical requirements, market conditions, and customer expectations are subject to constant changes. However, not all high-technology industries share an identical business environment. For example, the activities of biotechnology firms are closer to basic research and more related to public interest than other high-technology firms (Weisenfeld, Reeves, and Hunck-Meiswinkel 2001), and such firms operate in a relatively "winner-takes-all" atmosphere (Casper 2000). One major development in biotechnology may enable the firm to enjoy a few years of benefits. Other high-technology production systems such as nuclear energy plants may be operated by the government in a less competitive environment, stressing safety, rather than quality and efficiency (Jacobs, Keating, and Fernandez 2000).

In this study, we focus on electronics manufacturing firms as a distinctive type of firm in the high-technology industry sector. The electronics industry possesses highly inter-related and complex manufacturing operations with high dynamic tensions, the striving for high quality, flexibility, productivity, and timely delivery. Some researchers (Jayanthi and Sinha 1998; Shi and Gregory 1998) have suggested that high-technology manufacturing of this type is prototypical of future operations. This is because the rapid pace of technological changes, market volatility, and global competition are also becoming increasingly visible in some industries. For example, the automobile industry is having to confront rapid changes in design and technology (Divincenzo 1999; Howell 2003) and shrinking product development times (Winter 2003). Other industries such as mechanical and equipment manufacturing are guiding their operations managers towards achieving a more integrated and dynamic vision of production systems, and greater flexibility and shorter delivery times (Shi and Gregory 1998). Quality is particularly essential in a competitive marketplace (Deming 1986), but a complex and volatile environment is making it difficult to realize QM. An empirical QM model that is contingent on technology-based manufacturing operations that are competitive, complex, and volatile should have important theoretical implications and practical relevance for organizations entering a new era of operations. Thus, such a model is of particular interest for researchers of quality management. Although the electronics industry produces a wide range of products from printed circuit boards to semiconductors, electronics manufacturers are all operating in very similar business environments.

Traditional manufacturing strategy holds that operational performance is maximized when generic, operations-based capabilities of quality, delivery, flexibility, and cost are traded off (Anand and Ward 2004). However, Rosenzweig and Roth (2004) suggest that these generic competitive capabilities could be pursued simultaneously starting with conformance quality. Their empirical findings in high-tech industries support the paradigm that development of one generic manufacturing capability need not necessarily be at the expense of another. Accordingly, pursuing total quality is regarded as a primary strategy for improving various operations-based capabilities and overall organizational performance.

The aims of this research are to develop an empirical model for QMS in the electronics manufacturing industry, study how various quality elements relate to organizational performance, and, most importantly, explain the industry-specific factors leading to such relationships. We invited 225 electronics manufacturing firms in the rapidly developing electronics sector in Hong Kong and the Pearl River Delta (PRD) region of China to participate in our study. Based on the survey data, we developed a path analytic model. We also interviewed operations executives in the industry and compared our empirical model to other models in the literature, and studied how QM practices are contingent on their operating environment.

2. Operating Characteristics of Electronics Manufacturing

The world's electronics industry can be characterized in terms of some important and distinctive operating features. The industry is technology-based, fast-changing, and operates in an extremely competitive environment with very complex supply networks that emphasize quality, systems, and reliability (Ray 1990; Willett 1991; Beasley 1992; Cimento and Knister 1994; Correia 1999). Volatile technology is a hallmark of the electronics industry. Electronics firms often face extremely short product life cycles with constantly and rapidly changing product and process technologies (Fine 2000; Mallick and Schroeder 2005). With new technologies emerging quickly and customer requirements changing continually, speedy and timely operations are critical success factors, leading to competition that is essentially time-based (Gaimon and Morton 2005). In addition, the industry often faces the problem of over-supply, and because suppliers operate in a highly competitive global marketplace, their power to negotiate with customers is low.

The electronics industry operates within global supply networks that are particularly complex, as the industry uses complex and high value-added components or parts for which transportation costs are relatively low. Electronics products are often made up of components or parts supplied by specialized producers located in different geographical regions. Consistency and reliability are of particular concern, and "Six Sigma" or "Zero Defects" has become the industry norm (Graham 1993). Every process has a measure of variability to it, and a key to quality is to keep variations as close to the target as possible. As a result, quality control procedures for each tier of the supply chain have become increasingly strict. In multinational supply networks, industrial buyers often rely on a regional procurement office, which relies on the use of quality system standards as the major criteria for assessing suppliers (Yeung, Cheng, and Chan 2004). Electronics firms are consistently shaped by pressures from the industrial market and must be highly customer-oriented, excelling in responding to the many guidelines, standards or requirements set by their customers. With no alternatives, many companies have implemented ISO 9000 as a contractual requirement or to boost customer confidence. Formal quality systems and standards are highly emphasized in the electronics industry. More and more stringent QMS standards, such as QS-9000, originally designed mainly for the automobile industry, and TL 9000, stringent quality system requirements for telecommunication products, have been introduced to the industry. Large industrial buyers in electronics manufacturing have imposed rigid requirements on the QMS of their suppliers. An example is the procedures of the Quality System Review (QSR) (Harrold 1999), which is a standard much more stringent than ISO 9000.

Electronics products are often regarded by many countries, particularly those in the Asia-Pacific region, as being of strategic importance to industrial development. However, unlike other manufacturing industries, such as automobiles (Samson and Terziovski 1993; Chang 1995), the electronics industry in this region enjoys very little tariff protection in international trade, resulting in an extremely competitive market. Because of cutthroat competition, prices in the electronics industry have been under persistent downward pressure (Stout 1993; Cimento and Knister 1994; Correia 1999; Carrillo 2005). Previous studies (Cimento and Knister 1994) have reported that the average annual decline in prices for purchased parts has been approximately 10% per year, and that the steepness of this curve is unique to the electronics industry.

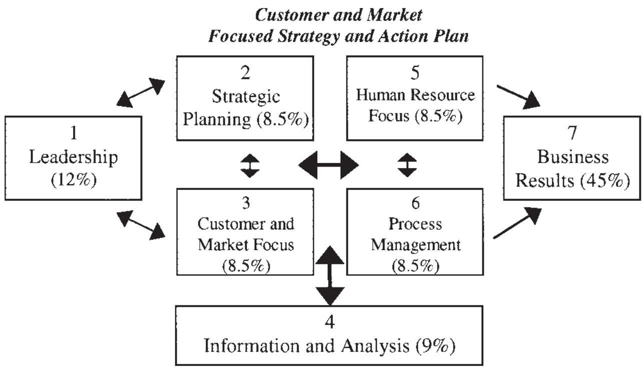
3. Literature Review and Hypothesis Setting

3.1. Theoretical and Empirical Models

Much empirical research has suggested that the relationship between QM practices and organizational performance is contingent on operating environment and industry type. However, models for quality awards and quality standards (e.g., ISO 9000) require adherence to a particular framework. This is evidenced by the rigid weights given by an award to each of the specific categories or criteria of quality in a model, and the fixed causal relationships among them assumed by the award. In contrast to empirical research, the emergence of award models such as the Malcolm Baldrige National Quality Award (MBNQA) and the European Quality Award (EQA) has brought a high and universal profile to QM practices (Sousa and Voss 2001). These quality award models are being followed by thousands of companies worldwide.

Established in 1987, the MBNQA has been widely recognized as a model of an exemplary quality management framework (Black and Porter 1996; Curkovic and Handfield 1996; Hendricks and Singhal 1997). In the MBNQA business model, leadership, strategic planning, and customer and market focus are tied together to symbolize a "leadership triad" that emphasizes the importance of top management leadership to strategy and customers (Figure 1). A human resources focus, process management, and business results are closely knitted together to represent the "results triad" in the model. Process management and a focus on human resources have a direct impact on business results. Since 1998, the two elements of customer and market focus, and customer focus results have been used in place of the previous category of customer focus and satisfaction. Customer and market focus is regarded as a quality driver, and customer focus results are listed under the category of business results. The main focus of the performance measures in MBNQA has been broadened from customer satisfaction to embrace the results of organizational effec-

Figure 1 **The Model of Malcolm Baldrige National Quality Award (MBNQA).**



tiveness and to include a focus on finance and marketing.

The European Quality Award represents another well-recognized model of quality (Binney 1992; Slack, Chambers, Harland, Harrison, and Johnston 1995). In the EQA model, leadership is described as the driver for improving people management, policy and strategy, and resources, which in turn enhance process management (Figure 2). On the other hand, process management is the only immediate factor leading to operational performance. Unlike the MBNQA model, customer focus and customer satisfaction are the same element in the EQA model. In the EQA model, customer satisfaction (20% of the total score), rather than other business results (15%), is regarded as the most important criterion. The model has not been revised since its introduction in 1992.

Apart from the theoretical models for quality awards, various empirical models have been developed in the literature. Their findings, however, are often inconsistent. Focusing on both the manufacturing and service industries, Powell's (1995) study suggests that leadership and cultural elements in quality management are more important than operational systems and process management. Zhao, Yeung, and Lee's (2004) study indicates that, in selected service industries, small companies that focus solely on leadership and cultural elements (e.g., training and quality teams), but that have no formal process management systems, can be very efficient. Some studies of general manufacturing industries also suggest that cultural elements directly produce performance results, without mediating through core practices such as systems controls and process management (Dow, Samson, and Ford 1999; Samson and Terziovski 1999). On the other hand, the studies of Flynn, Schroeder, and Sakakibara (1995) and Anderson, Rungtusanatham, Schroeder, and Devaraj (1995) of the electronics, transportation components, and machinery sectors show that cultural elements in QM, such as learning and teamwork, communications and cooperation, and so forth, do not directly affect organizational performance. They only create the environment to support process management. In other words, cultural elements will affect performance only when operational and process management systems have been established.

In short, the findings of these models are rather inconsistent, and certain features in the models may depend on the type or operating characteristics of their industry sector. Sousa and Voss (2002) pointed out that further research is needed to clarify the relative importance and interplay among leadership, cultural elements, and process management practices in determining performance outcomes under specific organizational contexts.

3.2. Development of Research Hypotheses

Quality management practices generally refer to an organized and integrated set of operational processes that deliver quality—the total features and characteristics of a product or service that bear on its ability to satisfy a given need—including organizational responsibilities, resources, procedures, and structures (ISO 1986; Yeung 1999). The classical theories on quality (Deming 1986; Crosby 1986; Juran 1989) suggest that quality management requires total commitment from the top. The resources needed and the internal cooperation required will come only when top management provides appropriate leadership (Goetsch and Davis 1995). Figure 3 shows general hypotheses on the overall relationships between various quality system components, called modules. Detailed hypotheses on the relationship between individual constructs in the QMS are also indicated by dotted arrows in the same figure. The implementation of an advanced QMS requires cultural changes in an organization (Glover 1993; Harber, Burgess, and Barclay 1993; Sinclair and Collins 1994). Goetsch and Davis (1995) stressed that it is critical for top management to model all of the quality behavior that they want employees to emulate. Leadership from top management downwards can gradually bring about changes in the attitudes of managers, and then of other supporting staff members. Support from senior executives and cooperation from other managers in efforts to achieve quality will pro-

Figure 2 **The European Quality Award Model.**

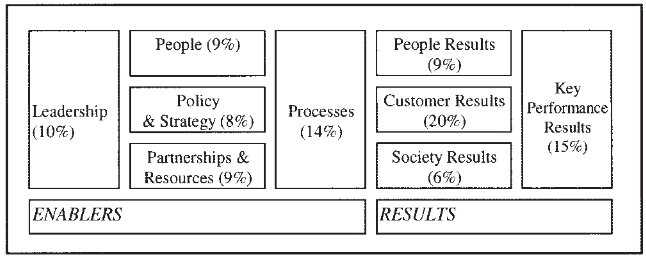
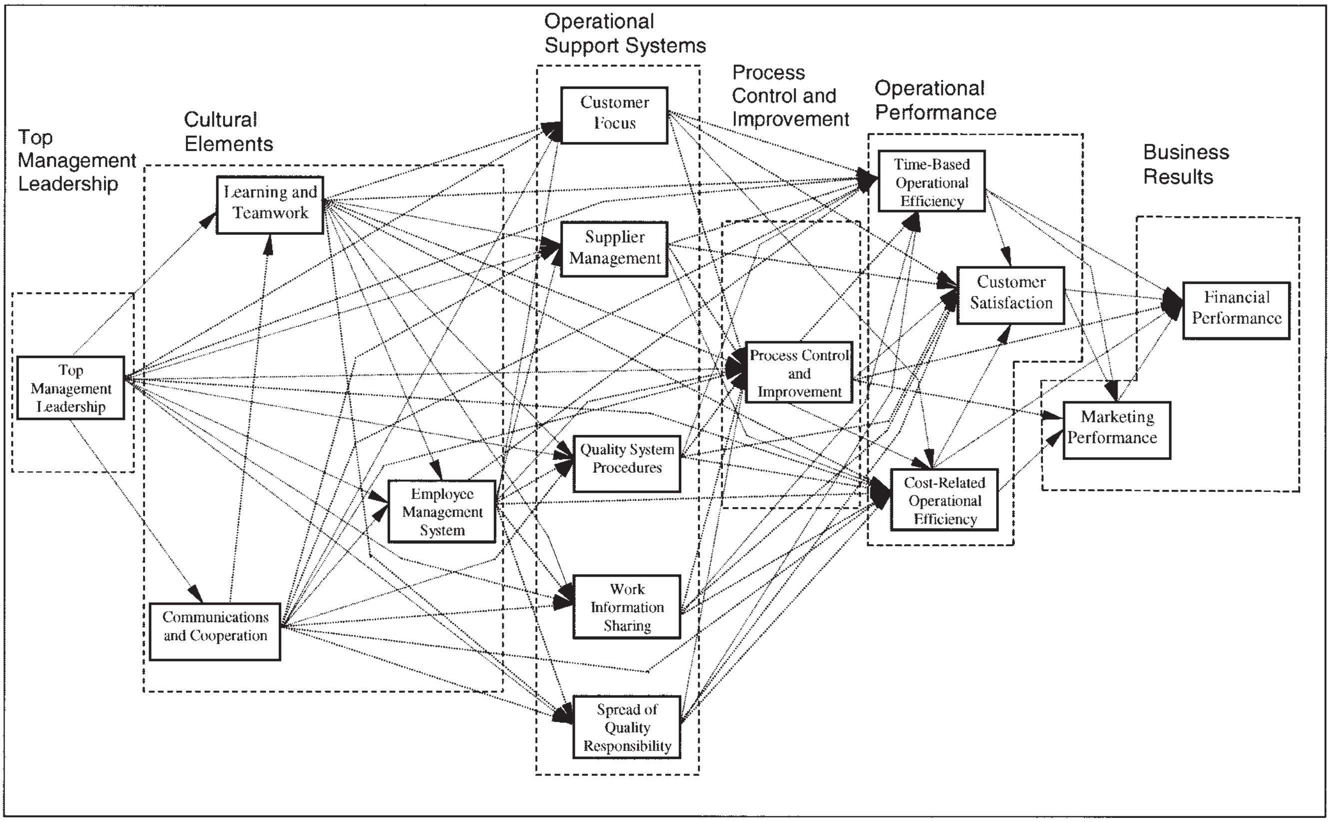


Figure 3 **An Analysis of Major Components in a Series of Chain Reactions in a Quality Management System and Organizational Performance Relationships.**



vide the necessary environment and resources for quality training and organizational learning (Miller 1993), and for developing teamwork. The attitudes of employees and management systems will then improve gradually (Juran 1989; Serpa 1991; Bounds, Yorks, Adams, and Ranney 1994; Doherty, Wells, and Ryan 1994; Anderson, Rungtusanatham, Schroeder, and Devaraj 1995; Choi and Behling 1997).

Accordingly, the first set of hypotheses, Hypothesis 1, is developed as follows:

H1. *Cultural elements are directly related to top management leadership.*

The development and operation of a QMS depend on the quality of the leadership exercised by top management and on the support of other staff members. A QMS must be supported by cultural elements, such as quality training and teamwork (Crosby 1979; Deming 1986; Juran 1989; Feigenbaum 1991). The structural and operational aspects of a QMS include customer focus, supplier management, quality system procedures, the sharing of work information, and the spread of responsibility for achieving quality (Juran and Gryna 1993; Yeung 1999). Process control and improvement is supported by the management system infrastructure and by cultural elements, such as the commitment shown by top management and the involvement of employees (Crosby 1979; Deming 1986; Garvin 1988; Bounds, Yorks, Adams, and Ranney 1994). As a result, the second and third sets of hypotheses are laid down as follows:

H2. *Operational support systems are directly related to cultural elements and top management leadership.*

H3. *Process control and improvement are directly related to operational support systems, cultural elements and top management leadership.*

Quality management practices have a significant effect on organizational performance (Deming 1986; Fynes and Voss 2001). Process control and improvement and operational systems in quality management, such as process control procedures and supplier management, play a crucial role in improving operational efficiency and customer satisfaction (Sluti 1992; Adams 1994). Top management leadership, communications and cooperation, learning and teamwork, and an employee management system support the development and operation of a QMS. In addition, they may also have a direct effect on operational performance, as has been found in some manufacturing sectors (Dow, Samson, and Ford 1999). Customer satisfaction may be directly influenced by both time-based and cost-related operational performances, and by the other elements in a QMS. Marketing performance may be directly affected by process management, operational efficiency and customer satisfaction. Financial performance may depend directly on other aspects of organizational performance and on QM practices (Sluti 1992; Juran and Gryna 1993; Flynn, Schroeder, and Sakakibara 1995; Powell 1995). The fourth and fifth sets of hypotheses are formulated as follows:

H4. *Operational performance is directly related to process control and improvement*, *operational support systems*, *cultural elements*, *and top management leadership*.

H5. *Business results are directly related to operational performance and process control and improvement*.

4. Research Design

This study was conducted in Hong Kong and in the PRD region of Guangdong, China. In recent years, Hong Kong's manufacturing industries have become fully integrated into the PRD region, which is currently the most profitable manufacturing base in China and one of the strongest production centers in the world (Hong Kong Productivity Council 1999; Graham 2000). The region attracts capital, technology and entrepreneurs from the U.S., Japan, Europe, and Taiwan, and has the largest number of international organizations in China. As these industries have moved towards the manufacturing of increasingly technology-intensive products to compete on a global basis, transfers of technology on a vast and rapid scale have taken place (Asiainfo Daily China News 2001). The electronics industry has emerged as the most prominent and fastest-developing field of technology in China (Asiainfo Daily China News 2001; Hand 2002). According to research from Converge Inc. (Singer 2002), China's semiconductor industry, currently accounting for 9% of worldwide sales, will increase to 12.2% by 2005, and the country will the word's largest consumer of semiconductors by 2010. Although the world's demand for chips decreased in 2001, the country's market grew by 18.3% that year.

Our study focuses on electronics firms in the PRD region that are headquartered in Hong Kong, or that have regional headquarters in Hong Kong responsible for research, logistics and marketing functions, while having their engineering and production functions located mostly on the mainland. The electronics industry in the PRD region is heavily export-oriented and, hence, is operating in a free and extremely competitive global market (China Daily 2001). In a competitive, fast-changing and technology-based operating environment, quality management is critical to survival and prosperity. A significant proportion of the electronics manufacturers in the PRD region are Original Equipment Manufacturers (OEM) or Original Design Manufacturers (ODM) with major customers (or their parent companies) in the U.S., Japan, and Europe. According to recent research, the total annual output of Hong Kong-based electronics manufacturers in the PRD region is approximately U.S. $42 billion. Total export output is about U.S. $28 billion. The U.S., Japan, and Singapore are the region's largest export markets for electronics products, accounting for 26.5%, 7.1%, and 6.8% of total exports, respectively. According to the latest census report, about 1,000 electronics manufacturing firms are based in Hong Kong.

A pilot study of six electronics firms was conducted prior to the launching of a large-scale survey study. Case research was carried out in these firms to pretest the survey questionnaire. About 330 companies were randomly selected from an electronics directory for further contact. A total of 302 electronics firms were contacted successfully. Of these, 246 companies were eventually invited to join the present research through multiple contacts with either senior management or with technical, administrative, or other managers. However, 21 firms dropped out of the study for various reasons, such as the complexity of the questionnaire or because of the confidentiality of the information being sought. A total of 225 useful questionnaires were received, yielding a response rate of 74.5% of the total number of companies successfully contacted. Such a high response rate was the result of a number of factors, including the application of effective survey strategies. For example, from a directory of the local electronics industry, we obtained a complete list of the names (with the corresponding positions and contact details) of the senior management of all of the companies. In addition, we promised the participants that we would benchmark their quality practices and provide them with individual and detailed analyses of their quality management systems. More than 20% of our sampled firms are international organizations from the U.S., Japan, the Netherlands and other countries.

The firms that agreed to participate in this study were required to appoint an administrator, normally a senior staff member such as the general manager or a director, who was responsible for administering the detailed survey questionnaire to different departments, and who served as a point of contact for the researchers. They were also responsible for arranging interviews for the researchers when required. This was helpful for the researchers when it came to arranging a series of in-depth investigations after an analysis of the survey data. Depending on their position and the availability of data, the administrator was also normally one of the major respondents to the questionnaire. As a result, we laid down the requirement that the administrator must have worked for at least three years in the company. The profile of the administrators is shown in Table 1.

We had taken a few measures to ensure the quality of the data collected. We insisted that the data concerning management practices and organizational performance must be filled by different members of staff. For instance, the operations manager who filled in the measures of operational efficiency should not report on QM practices. In addition, the indicators of a construct were sometimes filled by different departments. For example, "customer focus" concerns both product design processes and customer surveys, which are carried out by different functional divisions. We mandated that marketing and financial performances must be reported by appropriate personnel in the marketing and accounting departments, respectively, based on actual figures or measures. The quality of the data collected was further assured by qualitative investigations to be discussed later.

The questionnaire survey took about 15 months to conduct. It was followed by an analysis of the data. A preliminary data analysis shows that the average number of employees of the sampled companies was 1,690, with a standard deviation of 2,640. The number of employees in most firms ranged from 200 to 5,000, while six companies reported having over 10,000 employees. Over 60% of the organizations were organized in line productions, followed by batch processes (25%), continuous flow (10%), and job shop (4%). Forty-four percent of them (99 firms) were ISO 9000 certified.

A total of 16 companies were strategically selected and contacted for in-depth interviews in the final stage of this study. Based on another study (Yeung 1999), we classified the quality systems in these organizations into four types, namely undeveloped, framed, accommodating and strategic, in accordance with the level of advancement of their QM practices. Four companies from each type were selected to ensure that organizations with different levels of QM practices were interviewed. The interviews were conducted in either the offices or the factories of these companies, whether in Hong Kong or in the PRD region. These qualitative investigations were conducted for two major purposes. First, we tried to verify the quantitative data reported in the questionnaire. We selected two to three departments in each firm and carefully audited their responses to the questionnaire by cross-checking the organizational records and examining the actual figures. We paid special attention to the answers to some behavioral questions, verifying if they actually reflected daily operational practices. Our triangulation effort with these companies suggests that the accuracy of the reported data was not a concern. Second, we sought qualitative explanations for the quantitative data collected from the survey questionnaires. By interviewing quality and operations professionals, we also explored the operating characteristics of the electronics industry. We attempted to interview management executives and staff at different levels in the organizations, including operators, workers and members of Quality Control Circles, if available. We spent a full day at each of the plants we visited and reviewed some quality systems documents for purposes of verification.

Table 1 Positions of the Administrators

Positions	Frequency	Percentage
Top Management (e.g., Managing Director)	79	35.1%
Senior Technical Managers (e.g., Operations Manager)	59	26.2%
Senior Non-technical Managers (e.g., Human Resources Manager)	52	23.1%
Other Managers (e.g., Production and Material Control Manager)	22	9.8%
Chief/Senior Engineers (e.g., Chief Manufacturing Engineer)	13	5.8%
Total	225	100%

4.1. The Survey Instrument

The quantitative analysis in this study is based on a research instrument developed by Yeung (1999) for measuring QM practices and organizational performance (see the Appendix). Based on an extensive review of the QM literature, the instrument was developed comprising constructs that were derived mainly through an exploratory factor analysis, and verified empirically for reliability and validity. The measurement of QM practices consists of a wide range of factors, such as top management leadership, customer focus and supplier management. A list of the independent and dependent constructs is presented in Table 2. The selected indicators for the constructs are generally similar to previous research in this area (Flynn, Schroeder, and Sakakibara 1994; Black and Porter 1996). For example, the indicators for "customer focus" include "acquiring customer information," "analyzing customers' feedback," "working with customers in product design," and so forth. Organizational performance is a measure of a firm's success and achievements. Five aspects of organizational performance are assessed in this study. They are time-based operational performance, cost-related operational performance, customer satisfaction, and marketing and financial performance. A scale of one to seven, with a rating of seven indicating the best performance measure, was used.

4.2. Reliability and Validity of the Instrument

The instrument demonstrates good reliability and validity. All of the Cronbach's alpha values for all scales

Table 2 The Results of Path Analysis (Only Hypotheses 4 and 5 are shown)

Hypotheses	Dependent Variable	*F*	Probability	R^2	VIF	Independent Variable	*P*	*t*	*p*-values
Hypothesis 4	**Time-based Efficiency** (e.g., Timeliness of Delivery, Manufacturing Lead-time, etc.)	26.464	.000	.115	2.911	Top Management Leadership	−.118	−.1148	.252
					1.807	Communications and Cooperation	.027	.328	.743
					2.048	Learning and Teamwork	−.008	−.093	.926
					2.160	Employee Management System	.089	1.004	.307
					2.305	Customer Focus	.181	1.975	.047*
					2.246	Supplier Management	−.031	.347	.729
					2.255	Quality System Procedures	−.016	−.172	.864
					2.055	Work Information Sharing	−.020	−.235	−.814
					1.178	Spread of Quality Responsibility	−.035	−.533	.595
					2.305	Process Control and Improvement	.286	3.125	.002**
	Cost-Related Efficiency (e.g., Total Quality Costs, Unit Cost of Manufacturing, Engineering Changes Costs, etc.)	19.208	.000	.079	2.754	Top Management Leadership	.035	.330	.742
					1.739	Communications and Cooperation	−.061	−.714	.476
					1.966	Learning and Teamwork	.113	1.261	.209
					1.820	Employee Management System	.141	1.638	.103
					2.305	Customer Focus	.028	.283	.777
					2.200	Supplier Management	−.019	−.198	.843
					2.225	Quality System Procedures	.020	.206	.837
					1.968	Work Information Sharing	.070	.778	.437
					1.174	Spread of Quality Responsibility	−.117	−1.694	.092
					1.000	Process Control and Improvement	.282	4.383	.000**
	Customer Satisfaction (e.g., Customer Complaints, Loss of Customers, Product Reputations, etc.)	70.501	.000	.321	2.347	Customer Focus	.021	.289	.773
					2.201	Supplier Management	.009	.130	.897
					2.225	Quality System Procedures	−.019	−.262	.794
					1.973	Work Information Sharing	−.038	−.557	.578
					1.190	Spread of Quality Responsibility	.085	1.628	.105
					1.240	Process Control and Improvement	.243	4.540	.000**
					1.361	Time-Based Operational Efficiency	.496	8.837	.000**
					1.215	Cost-Related Operational Efficiency	.125	2.355	.019*
Hypothesis 5	**Marketing Performance** (e.g., Sales Volume, Profit Margins, Market Share, etc.)	27.196	.000	.148	1.329	Process Control and Improvement	.048	.686	.493
					1.806	Time-Based Operational Efficiency	.158	.1966	.071
					1.182	Cost-Related Operational Efficiency	.186	2.840	.005*
					1.182	Customer Satisfaction	.337	5.145	.000*
	Financial Performance (e.g., Return on Investment, Overall Profitability, etc.)	373.021	.000	.626	1.068	Process Control and Improvement	−.021	−.504	.615
					1.169	Time-Based Operational Efficiency	.004	.091	.928
					1.112	Cost-Related Operational Efficiency	.035	.809	.420
					1.201	Customer Satisfaction	.021	.475	.635
					1.000	Marketing Performance	.791	19.314	.000**

$^* p < 0.05$, $^{**} p < 0.01$, NS = Not Significant.

on QM practices ranged from 0.719 to 0.936, with an average of 0.842. The Cronbach's alpha values for the constructs on organizational performance were somewhat lower, ranging from 0.646 to 0.866, with an average of 0.773. The overall reliability for QM practices and organizational performance is considered to be very satisfactory (Nunnally 1967; Litwin 1995).

The content validity of the current instrument was assured by an extensive review of the literature and by the expert judgment of quality and operations management professionals in the industry. In addition, a long questionnaire of 10 pages, comprising more than 70 research questions and providing extensive coverage of the relevant research issues, assured that the theoretically related subjects were comprehensively sampled. The construct validity of the present instrument was assessed by factor analysis. The factor loading indicates the correlation between an indicator and its corresponding factor. A high factor loading gives evidence of construct validity. All of the constructs here had an average factor loading of at least 0.56, indicating a satisfactory representation of the indicators (Kline 1994). The total variance explained by the factor(s) for nearly all constructs was higher than 50%, which ensured the practical significance of the derived factors (Hair, Anderson, Tatham, and Black 1998). The factors derived from the factor analysis were further assessed by unifactorial tests (Nunnally 1967; Black and Porter 1996). The idea is that if each factor is valid as a construct, then its set of variables would once again form a single factor. All 15 factors exhibited a unifactorial nature.

Criterion-related validity is another important consideration. Quality management systems and activities were presumed to be predictors of organizational performance. The correlations between the QMS constructs and organizational performance were computed. The correlation matrix shows that most of the predictor variables (from QMS) were significantly related ($p < 0.01$) to the criterion variables of organizational performance, providing evidence of the criterion-related validity of the instrument.

Both convergent validity and discriminant validity were examined by using a Confirmatory Factor Analysis (CFA). Generally, a construct with either a reliability loading of at least 0.5, a significant *t*-value ($t > 2.0$), or both, is considered to have demonstrated convergent validity (Fornell and Larcker 1981; Chau 1997). Only one item indicated a relatively low reliability loading (standardized loading = 0.451). Nevertheless, its *t*-value was highly significant ($t = 4.53$, $p < 0.01$). All other items had standardized loadings higher than 0.5, ranging from 0.551 to 0.941, with an average of 0.715. All *t*-values were higher than 2.70, implying that the relationships between the indicators and constructs were statistically significant. The multistep procedures suggested by O'Leary-Kelly and Vokurka (1998) were then applied to further examine convergent validity. The constructs were tested in pairs or by dividing them into various sets. In the first step, all null models were rejected ($p < 0.05$). Two constructs ("work information sharing" and "spread of quality responsibility") in the "trait only model" test were accepted ($p > 0.05$) in the second step. A significantly better fit was not found with the "trait-method models" (χ^2 decreased by 11.30 and *df* by 5). Nevertheless, all measures of the factor loading of the "trait only model" were statistically significant. During the third stage of the tests, all other "trait-method models" were accepted ($p > 0.05$), while none of the "method only models" led to an acceptable fit ($p < 0.05$). All latent variable factor loadings of the "trait only models" were statistically significant. The multistep tests provided further evidence of convergent validity.

Discriminant validity can be judged by fixing the correlation between various constructs to 1.0, then re-estimating the fixed model. A significant difference in the chi-square statistics between the fixed and unconstrained models indicates a high discriminant validity (Fornell and Larcker 1981; Chau 1997). By pairing all possible combinations of the constructs for separate comparisons and fixing their correlations to a perfect correlation of 1, the chi-square values increased substantially, ranging from 9.95 to 288.00, with an average change of 108.80. With changes in one degree of freedom, these values were significant at the $p = 0.01$ level ($\chi^2 > 6.635$).

4.3. Modeling Using Path Analysis

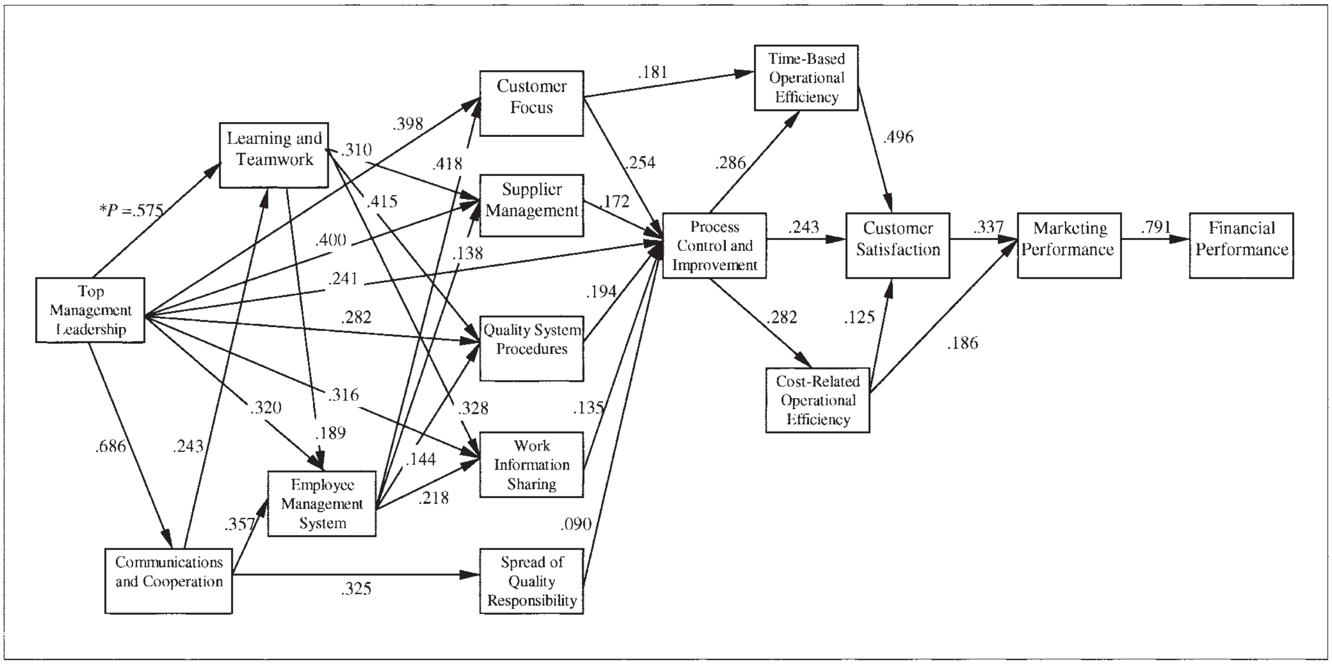
Modeling is a process of formalizing a framework for interpreting a phenomenon or relationships by abstracting from a reality that is otherwise too complex to understand (Davis 1985; Bradley and Schaefer 1998). There are perhaps thousands of QM activities in an organization and every activity is likely to have an effect on organizational performance (Bounds, Yorks, Adams, and Ranney 1994; Kolarik 1995). A QM model generalizes these activities and summarizes them in a typical framework that portrays their relationships. Modeling is also a process of building and testing theories (Flynn, Schroeder, and Sakakibara 1995; Bradley and Schaefer 1998). When models are used in building theories and analyzing systems (Li 1975), the goal is to define a set of equations that correspond to the actual causal process in the real world (Heise 1969).

Path analysis (Li 1975) is a classical statistical technique for building complex empirical models. Other similar methods, such as structural equation modeling (SEM), are essentially confirmatory techniques and are more appropriate for verifying a few simple and well-defined models. Using SEM to develop complex models, e.g., models with more than seven unobservable constructs and 20 indicators, will always lead to the rejection of these models, regardless of their validity (Bentler and Chou 1987; Baumgartner and Homburg 1996). In a path analysis, the coefficient of determination (R^2) measures the proportion of the variance of a dependent variable explained by a set of independent variables. A standardized partial correlation coefficient, which represents the path coefficient (P), measures the strength of the relationship between a dependent and a predictor variable when the predictive effects of the other independent variables in the regression model have been removed (i.e., stepwise regression). A relatively stringent threshold, i.e., a significance level of 0.05, was used in this study to retain paths. This conservative criterion enhances the reliability of the path model (Asher 1983; Flynn, Schroeder, and Sakakibara 1995).

5. Results and the Model

These complex relationships based on the path analysis of the above hypotheses and their corresponding path coefficients are presented in Figure 4. The variance inflation factor (VIF), which indicates the degree to which each predictor variable is explained by other predictor variables, is a common measure of multicollinearity in a path analysis (Hair, Anderson, Tatham, and Black 1998; Sharma 1996). High multicollinearity masks the effects of an individual predictor, and results in incorrect estimations of regression weights (Heize 1975; Hair, Anderson, Tatham, and Black 1998). A threshold VIF that is less than or equal to 10 is commonly suggested (Heize 1975; Billings and Wroten 1978; Asher 1983). All VIFs in the path model were

Figure 4 The Quality Management Model in the Electronics Industry.



less than 3.5, providing solid evidence against multicollinearity.

The results show that top management leadership is directly related to communications and cooperation, learning and teamwork, and to employee management system. The path coefficients (P) ranged from 0.320 to 0.686 ($p < 0.001$). The results further show that communications and cooperation is directly related to learning and teamwork and to the employee management system, and that learning and teamwork is directly related to the employee management system. Hypothesis 1 was fully supported.

Hypotheses 2 and 3 received weaker statistical support and some of the hypothesized relationships were rejected. For example, customer focus is *directly* dependent on top management leadership ($P = 0.398$, $p < 0.001$) and on the employee management system ($P = 0.418$, $p < 0.001$), but not on communications and cooperation ($P = 0.052$, $p = 0.436$), or on learning and teamwork ($P = 0.127$, $p = 0.073$). In this study, the employee management system refers to the ways by which employees are managed and motivated to improve quality. The results show that a good employee management system supports customer focus practices, supplier management, quality system procedures and work information sharing. In addition, we found that process control and improvement is directly dependent on various operational systems such as quality system procedures and customer focus practices, as well as on top management leadership. However, process control and improvement is not directly affected by cultural elements such as learning and teamwork. Instead, such an effect is mediated through other constructs in the QMS (Figure 4).

Hypotheses 4 and 5 postulate the causal relationships among the QMS constructs and organizational performance. Time-based operational efficiency was postulated to be directly influenced by all of the constructs in a QMS. However, the results of the path analysis show that time-based efficiency is directly influenced only by process control and improvement ($P = 0.286$, $p = 0.002$) and by customer focus ($P = 0.181$, $p = 0.047$). The variance explained (R^2) was 0.115, implying that 11.5% of the total variance in time-based efficiency can be accounted for by these two constructs. Cost-related operational efficiency is directly dependent only on process control and improvement ($P = 0.282$, $p < 0.001$). Customer satisfaction is directly influenced by time-based operational efficiency, cost-related efficiency and process control and improvement. The variance explained (R^2), the individual path coefficients (P) and the corresponding p-values are shown in Table 2 (due to space limitations, only the values for Hypotheses 4 and 5 are presented).

The effects in a path analysis can be decomposed into direct, indirect and spurious effects. Both direct and indirect (mediating) effects are "real" effects. Total effects are the sum of direct and indirect effects. They represent the extent to which a construct is influenced by others. Based on the path diagram in Figure 4, we decomposed the paths and computed the direct, indirect and total effects (Asher 1983; Flynn, Schroeder, and Sakakibara 1995) as shown in Table 3.

Table 3 Analysis of Total Effects and Model Fitness

Dependent Variable	Independent Variable	Direct Effect	Indirect Effect	Total Effect	Spurious Effect	Sum of Paths	Implied Correlation	Difference
Time-based Efficiency	Top Management Leadership	.000	.352	**.352**	.000	.352	.313	.039
	Communications and Cooperation	.000	.073	.073	.228	.301	.308	.007
	Learning and Teamwork	.000	.075	.075	.190	.265	.309	.044
	Employee Management System	.000	.129	**.129**	.187	.316	.360	.044
	Customer Focus	.181	.073	**.254**	.088	.342	.396	.054
	Supplier Management	.000	.049	.049	.165	.214	.309	.095
	Quality System Procedures	.000	.055	.055	.131	.186	.316	.130
	Work Information Sharing	.000	.039	.039	.153	.192	.304	.112
	Spread of Quality Responsibility	.000	.026	.026	.021	.047	NS	.047
	Process Control and Improvement	.286	.000	**.286**	.105	.391	.422	.031
Cost-Related Efficiency	Top Management Leadership	.000	.223	**.223**	.000	.223	.328	.105
	Communications and Cooperation	.000	.042	.042	.122	.164	.149	.015
	Learning and Teamwork	.000	.060	**.060**	.115	.175	.255	.080
	Employee Management System	.000	.052	.052	.076	.128	.267	.139
	Customer Focus	.000	.072	**.072**	.087	.159	.224	.065
	Supplier Management	.000	.049	.049	.097	.146	.199	.053
	Quality System Procedures	.000	.055	.055	.078	.133	.218	.085
	Work Information Sharing	.000	.038	.038	.089	.127	.233	.106
	Spread of Quality Responsibility	.000	.025	.025	.011	.036	NS	.036
	Process Control and Improvement	.282	.000	**.282**	.000	.282	.282	.000
Customer Satisfaction	Top Management Leadership	.000	.382	**.382**	.000	.382	.389	.007
	Communications and Cooperation	.000	.077	.077	.233	.310	.356	.046
	Learning and Teamwork	.000	.096	.096	.207	.303	.336	.033
	Employee Management System	.000	.116	**.116**	.168	.284	.318	.034
	Customer Focus	.000	.197	**.197**	.129	.326	.416	.090
	Supplier Management	.000	.072	.072	.177	.249	.362	.113
	Quality System Procedures	.000	.081	.081	.142	.233	.356	.133
	Work Information Sharing	.000	.057	.057	.163	.220	.331	.111
	Spread of Quality Responsibility	.000	.038	.038	.021	.059	.229	.170
	Process Control and Improvement	.243	.177	**.420**	.052	.472	.488	.016
	Time-Based Operational Efficiency	.496	.000	.496	.109	.605	.649	.044
	Cost-Related Operational Efficiency	.125	.000	.125	.124	.249	.393	.144
Marketing Performance	Top Management Leadership	.000	.170	**.170**	.000	.170	.239	.069
	Communications and Cooperation	.000	.034	.034	.101	.135	.194	.059
	Learning and Teamwork	.000	.044	.044	.091	.135	.240	.105
	Employee Management System	.000	.049	**.049**	.071	.120	.228	.108
	Customer Focus	.000	.081	**.081**	.060	.141	.182	.041
	Supplier Management	.000	.033	.033	.078	.111	.220	.109
	Quality System Procedures	.000	.038	.038	.062	.100	.265	.165
	Work Information Sharing	.000	.027	.027	.071	.098	.160	.062
	Spread of Quality Responsibility	.000	.017	.017	.009	.026	.167	.141
	Process Control and Improvement	.000	.194	**.194**	.018	.212	.252	.040
	Time-Based Operational Efficiency	.000	.167	.167	.057	.224	.380	.156
	Cost-Related Operational Efficiency	.186	.042	.228	.041	.269	.318	.049
	Customer Satisfaction	.337	.000	.337	.039	.376	.409	.033
Financial Performance	Top Management Leadership	.000	.134	**.134**	.000	.134	.177	.043
	Communications and Cooperation	.000	.027	.027	.080	.107	.194	.087
	Learning and Teamwork	.000	.035	.035	.072	.107	.174	.067
	Employee Management System	.000	.039	**.039**	.056	.095	.186	.091
	Customer Focus	.000	.064	**.064**	.048	.112	NS	.112
	Supplier Management	.000	.026	.026	.062	.088	.188	.100
	Quality System Procedures	.000	.030	.030	.049	.079	.254	.175
	Work Information Sharing	.000	.021	.021	.056	.077	NS	.077
	Spread of Quality Responsibility	.000	.013	.013	.007	.020	.134	.114
	Process Control and Improvement	.000	.153	**.153**	.014	.167	.180	.013
	Time-Based Operational Efficiency	.000	.132	.132	.045	.177	.304	.127
	Cost-Related Operational Efficiency	.000	.186	.186	.032	.218	.283	.065
	Customer Satisfaction	.000	.267	.267	.031	.298	.342	.044
	Marketing Performance	.791	.000	.791	.000	.791	.791	.000

NS = Not Significant.

The boldfaced figures highlight the finding that top management leadership, employee management system, customer focus, and process control and improvement have the greatest impact on time-based operational performance. Similar results were found on other aspects of organizational performance as shown in Table 3, implying that they have the greatest influence on organizational performance.

A spurious effect in a path analysis, on the other hand, is not a "real" effect. It is a covariance between two variables induced by a third variable that has a causal effect on the two variables simultaneously. The sum of paths is the total of the direct, indirect and spurious effects. An implied effect is the unpartialled correlation between two variables. If a model describes a real world situation *perfectly*, the unpartialled correlation between any two variables should be numerically equal to the sum of the paths (Flynn, Schroeder, and Sakakibara 1995). In contrast, a large difference between the implied correlation and the sum of paths implies misspecifications in the model, or the exclusion of some important constructs. Generally, a model with an average difference of less than 0.1 indicates a good fit (Asher 1983; Flynn, Schroeder, and Sakakibara 1995). The average difference between the implied correlation and the sum of the paths in our model was 0.078, suggesting a good model specification. The differences between the sum of the paths and the implied correlation for Hypotheses 4 and 5 are also shown in Table 3. In terms of the type of process mentioned in Section 4, we found this has no effect on quality management practices and organizational performance ($p > 0.213$).

6. Discussion

6.1. The Chain Effects

Our empirical QM model for the electronics industry indicates that quality constructs can be classified into a few major system modules, and that each module has a unique role in the system. Top management leadership is the driver of the entire QMS, leading to advances in cultural elements such as learning and teamwork, which in turn support the operational systems in quality management. However, except for customer focus (which directly influences time-based operational efficiency), the operational support systems do not impact directly on organizational performance (Figure 4). On the other hand, process control and improvement is the key driver of operational performance and customer satisfaction. Accordingly, a comprehensive QMS in the electronics industry is supported by four key modules as summarized and depicted in Figure 3, namely top management leadership, cultural elements, operational support systems, and process control and improvement. They create a series of chain effects impacting directly on organizational performance, rather than being parallel components. Although the first three areas are important components supporting the entire QMS, they have little or no direct impact on operational performance.

6.2. Constructs of Universal and Context Dependence

The literature consistently emphasizes the importance of top management commitment to quality, and this is supported in a number of studies. Theoretical quality models such as MBNQA and EQA suggest that top management leadership is the driver of all quality initiatives. Our empirical model from the electronics industry (Figure 4), as well as many other models, supports the importance of top management leadership. We found that top management leadership directly influences cultural elements, operational support systems, and process management. Anderson, Rungtusanatham, Schroeder, and Devaraj (1995) found that visionary leadership significantly enhances internal and external cooperation, and learning and process management. Flynn, Schroeder, and Sakakibara (1995) suggested that top management support is the basis for improving a wide range of organizational practices, including product design, the management of supplier relationships, workforce management, and work attitudes. Similar findings were found in other industrial settings, such as the service industry (Zhao, Yeung, and Lee 2004), other manufacturing industries (Samson and Terziovski 1999; Dow, Samson, and Ford 1999), and a mix of both (Powell 1995). It seems that the importance of top management leadership is universal across all types of industries.

However, the role of cultural elements and process management in quality management may be contingent on the operating environment. Zhao, Yeung, and Lee (2004) found that, in service settings, cultural elements are much more important than process management. A similar conclusion was reached in other studies on general manufacturing and service settings, as discussed before. Our study of the electronics industry, and Flynn, Schroeder, and Sakakibara's (1995) study of the electronics industry and other technology-based industries, indicates that cultural elements are supporting elements in a QMS—they do not directly affect organizational performance. Our qualitative investigations of 16 electronics firms suggest that the operational processes in this industry are generally developed by technical experts for well-defined tasks. Unlike those in other industrial settings, quality-control procedures are particularly rigorous in the electronics industry. Thus, the influence of cultural elements (human factors) on business performance in this industry is only indirect.

6.3. The Importance of the Constructs in the Electronics Industry

The model shows that the most important QM construct in the electronics industry that leads directly to organizational performance is process control and improvement (Figure 4). Process control and improvement refers to a series of operational control procedures and efforts at continuous improvement, such as minimizing deviations from target points. As shown in Figure 4, process control and improvement not only make possible timely and cost-efficient operations, but also lead directly to customer satisfaction.

An analysis of the total effects of the 10 constructs of a QMS (see Table 3) reveals that process control and improvement, top management leadership and customer focus are the most influential factors for organizational performance. These findings reveal the possibility of developing an effective QMS for the electronics industry by pinpointing three critical areas. In particular, other case studies (Yeung and Chan 1998) have revealed that some organizations in this industry have developed their QMS with a focus mainly on quality teams, quality training, or quality system procedures, resulting in poor operational performance. In a dynamic manufacturing environment, the primary need of any company is to implement an effective process assurance system and to be proactive in taking the initiative to make improvements. The success of such a system requires strong leadership from top management and the system must be anchored carefully to satisfy customer needs. The system can be considerably strengthened by the gradual development of the fourth construct—an appropriate employee management system (refer to Table 3).

Customer focus is the only construct in operational support systems (Figure 4) that leads to time-based efficiency ($P = 0.181$). However, its impact on cost-related efficiency is insignificant. In turn, time-based efficiency is a more important criterion ($P = 0.496$) than cost-related efficiency ($P = 0.125$) in garnering customer satisfaction. Our interviews in the final stage with the executives of the electronics firms confirm that time-based efficiency is regarded as the primary performance requirement for customer satisfaction. Operating in a highly competitive marketplace with low negotiating power, electronics suppliers are highly customer-oriented. With volatile technology, time-based efficiency is thus the primary consideration (Mallick and Schroeder 2005). The primary concern of many operations managers is to satisfy customers by providing the required products according to the agreed schedules. Although customers are also concerned about cost-effectiveness in their supplier companies, these data, as well as the criteria for assessing them, are not readily available. However, the model suggests that cost-related efficiency (total effects = 0.228) is, in fact, more important than time-based efficiency in marketing and financial performance (total effects = 0.167). Marketing performance here refers to both sales volume and profit margins, which are closely related to overall profit (i.e., financial performance; $P = 0.791$). Cost-related efficiency seems to represent an overlooked, but significant opportunity.

Our model differs from the quality award models in several ways. The MBNQA model sees human resources management and process management as impacting directly on business results. The EQA model suggests that employee management and satisfaction are the key elements of quality (18% of the total weighting), not process management (14%), or leadership (10%). However, our model indicates that process control and improvement, and customer focus—the former in particular—have the most direct effect on organizational performance. The MBNQA model suggests that all quality constructs have a similar importance (in terms of weighting). However, our analysis suggests that, in the electronics industry, process management and leadership are much more influential factors than the other factors.

7. Conclusions

We have empirically identified the following characteristics of a typical QM model in the electronics industry. A QMS in the industry is made up of four major modules: leadership, cultural elements, operational support systems, and process control and improvement. They create a series of chain effects, rather than acting as parallel modules with an equal impact, on business results. In a fast-changing industry with volatile technology and complex operations, process control and improvement is the key construct that directly affects organizational performance. It is followed by top management leadership and customer focus. Top management leadership provides resources and support to process management, while customer focus assures that process management is anchored to the market. This is in line with a previous study on the integration of marketing and quality (Lai and Cheng 2005). Although the importance of leadership appears to be universally applicable, the impact of other constructs is context dependent. We suggest that electronics manufacturers develop their QMS by primarily stressing process control and improvement, top management leadership, and customer focus, and then the development of an appropriate employee management system and other operational systems.

The limitations of this paper can be viewed in terms of both methodology and scope. Methodologically, the quantitative data collected here are based on self-reported questionnaires. Although in-depth interviews and industrial visits were carried out to verify the data, individual biases in reporting were bound to exist. The present study is based on cross-sectional survey research, which provides limited longitudinal evidence on exactly how each QM construct affects the others. In terms of the scope of the study, this research is limited to the areas of Hong Kong and the PRD region. Nevertheless, by including a considerable number of internationally based corporations in our study, we have enhanced the generalizability of our findings. For further research, a direct comparison of the electronics industry with a non-technology-based manufacturing sector, such as plastics products, clothing, wood furniture, etc., to verify the above findings would be worthwhile.

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