THE IMPACTS OF QUALITY MANAGEMENT PRACTICES ON INNOVATION

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Abstract

Researchers have explored the relationship between quality management (QM) and innovation in a variety of ways. A review of the literature, however, shows a few research gaps in the existing studies. There is a relative dearth of empirical studies on the interrelationships among QM practices and how they affect innovation. Moreover, there is no consistency among previous studies on the contribution of QM to innovation. While some studies have found that QM practices are positively related to innovation, others have concluded that there is no evidence of such a link. Further, the empirical studies are limited to assessing only a few types of innovation and fail to test the interaction effects of contextual variables.

The purpose of this study is three-fold: to investigate the impact of QM practices on five different types of innovation, to explore the relationships between behavioural and mechanistic QM practices, and to test the interaction effects of contextual variables. Using structural equation modeling (SEM), the proposed framework and hypotheses based on a sample of 223 ISO 9001 certified companies in Canada were empirically tested. The results indicate that QM practices have either a direct or indirect effect on innovation. Behavioural QM practices, such as management leadership and training, are significantly related to mechanistic QM practices, such as process management and product design. On the other hand, there is no interaction effect of moderating variables in the relationship between QM and innovation. This research contributes to the literature in three ways: it enables academics and practitioners to understand how and why QM practices foster innovation, it provides empirical evidence about the ways behavioural QM practices are related to mechanistic QM practices, and it enhances the understanding of the contextual effects of moderating variables.

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1. Research motivation and research objective

Over the past 30 years, innovation has caught the attention of researchers and practitioners (Gatignon *et al.*, 2002; Damanpour, 1987). In a turbulent economic environment, innovation is a strategic driver to seize new opportunities and protect knowledge assets (Hurmelinna-Laukkanen *et al.*, 2008; Moguilnaia *et al.*, 2005; Teece, 2000). Specifically, innovation plays a key role in providing unique products/services, creating new values that were not recognized, and establishing entry barriers (Lloréns Montes *et al.*, 2005). The value of innovation can also be explained by the increasing amount of expenditure for research and development (R&D), which is one of the most representative innovation areas. According to the latest report of the Organisation for Economic Cooperation and Development (OECD), the total gross expenditure on R&D in OECD countries increased annually by 4.9 per cent between 1995 and 2000; the real expenditure on R&D grew substantially by more than 33 per cent between 1995 and 2004 (OECD, 2006).

The importance of innovation has motivated researchers to identify various driving forces of innovation, such as internal or contextual factors (Becheikh *et al.*, 2006). Some researchers contends that quality management (QM) could be one of the prerequisites of innovation (Hoang *et al.*, 2006; Perdomo-Ortiz *et al.*, 2006). QM is broadly acknowledged to be a management model that is not only influencing operational and financial performance but also building competitive advantage (Kaynak, 2003). It is not surprising that many manufacturing and service firms around the world (e.g., Xerox, Ford, Motorola, and Federal Express) have adopted QM over the last two decades (Rahman, 2004; Powell, 1995). However, researchers still question

whether QM leads to innovation (Prajogo and Sohal, 2001). Along this line, QM researchers concentrate on exploring links or interaction effects between innovation and QM practices, such as management leadership, training, and process management.

While previous studies have provided interesting insight into the role of QM practices in innovation, a few shortcomings emerge from the literature review. First, there is a lack of empirical study on the contribution of QM to innovation (Hoang *et al.*, 2006; Martinez-Costa and Martinez-Lorente, 2008; Perdomo-Ortiz *et al.*, 2006; Prajogo and Hong, 2008; Singh and Smith, 2004). The literature review shows that only a few empirical studies theorized the relationship between QM and innovation since the early 2000s (e.g., Singh and Smith, 2004). Most studies by the late 1990s tested their hypotheses using case studies or a conceptual approach. Further, little attention was paid to the interaction effects among QM practices that would yield innovation.

Second, earlier studies provided mixed results on the impacts of QM on innovation. Some found that QM practices are positively related to innovation (e.g., Perdomo-Ortiz *et al.*, 2006; Martinez-Costa and Martinez-Lorente, 2008), whereas others concluded that there is no evidence linking QM activities and innovation (e.g., Singh and Smith, 2004; Moura E Sá and Abrunhosa, 2007; Prajogo and Sohal, 2004; Santos-Vijande and Álvarez-González, 2007). With respect to the identification of key QM practices, some researchers contended that only a few QM practices, but not nearly all QM practices, have a positive relationship with innovation (e.g., Perdomo-Ortiz *et al.*, 2006). Others, however, found that all QM practices are positively related to innovation (e.g., Martinez-Costa and Martinez-Lorente, 2008). Along the same line, prior studies provided conflicting evidence on whether behavioural QM practices – e.g., leadership and employee relations – are more significantly associated with innovation than mechanistic QM practices – e.g., process management and quality data (Feng *et al.*, 2006; Hoang *et al.*, 2006).

Third, prior empirical studies on the effects of QM were limited to assessing a few types of innovation. For instance, some discussed only a single type of innovation, such as product innovation (e.g., Prajogo and Sohal, 2004) or process innovation (Abrunhosa and Moura E Sá, 2008). Other studies dealt with only two types of innovation (product and process innovation). It can be argued that such a narrow view of innovation is a barrier that causes a misunderstanding of the impacts of QM on innovation. Little attempt was made to investigate the multidimensionality of the innovation construct that comprises radical, incremental, and administrative innovation. Therefore, a review of the previous studies gives rise to the following questions: How do QM practices link to innovation? How do behavioural practices influence mechanistic practices to result in innovation? Do QM practices have a significant impact on different types of innovation? Thus, this study concentrates on the research questions by conducting linkage-focused research on how QM practices influence various types of innovation. Along similar lines, the purposes of this study are:

- 1. To examine how QM practices impact five types of innovation: radical product, radical process, incremental product, incremental process, and administrative innovation.**
- 2. To investigate the relationships between behavioural QM practices and mechanistic QM practices.**
- 3. To test the interaction effects of moderating variables (firm size, the duration of QM adoption, structural control, structural exploration, and industry) on the relationship between QM practices and innovation.**

The remainder of this study is organized as follows. Section 2 examines the extant literature pertaining to QM practices, innovation typology, and the impacts of QM practices on innovation. Section 3 develops a theoretical framework and hypotheses. Section 4 presents methods, including data collection and measurement scales. Section 5 shows data analysis procedures and research findings. Finally, this study concludes with discussion, implications of the results, and directions for future research.

2. Literature review

This section discusses four important topics: the evolution of study about QM practices, the linkage-focused research on QM practices, the innovation typology, and the impacts of QM practices on innovation.

2.1. The evolution of study on QM practices

Since the 1930s, QM has caught the attention of researchers and practitioners (Abrunhosa and Moura E Sá, 2008). Traditionally, researchers considered QM to be a simple inspection-oriented system highlighting quality control in a scientific and rigorous fashion (Flynn *et al.*, 1994). In that period, quality activities mainly relied on results-oriented, narrow, and mechanistic approaches called “after the fact” control techniques (Mehra *et al.*, 2001). For example, statistical process control was used as one of the most popular techniques to identify variation and quality in systems (Rahman, 2004). However, in 1950s and 1960s, practitioners recognized many limitations of the inspection-based perspective when making an effort to enhance customer satisfaction and core competencies in mass production (Hendricks and Singhal, 2001). Highly competitive markets began to require organizations to implement the comprehensive managerial principles underlining behavioural aspects (Hafeez *et al.*, 2006).

To survive in the new paradigm, organizations changed the direction of QM from an inspection focus to a market-based orientation (Idris and Zairi, 2006). It was necessary for organizations to identify and improve the root causes of quality problems before delivering

products or services to customers. To reflect the change, organizations paid attention to organization-wide philosophies, such as the involvement of all employees, customer relations, and a long-term improvement process (Mehra *et al.*, 2001). In the early 1980s, QM technical methods and behavioural concepts were integrated and developed into a comprehensive management philosophy: TQM (Rahman, 2004). Many researchers seriously explored the implementation of TQM (Waldman, 1994). While previous researchers made efforts to gain clear insights into the implementation of QM, the majority of empirical studies on QM suffered from a narrow focus and a lack of rigor in terms of validity and reliability issues. In particular, the discussion of QM practices itself barely received any significant attention in empirical studies (Flynn *et al.*, 1994). Researchers, however, recognized that examining QM practices is an essential and primary prerequisite to provide effective management and competitive survival (Nair, 2006). Along this line, since the late 1980s much attention has been devoted to developing the measurement constructs of QM and examining the net impacts of QM practices (Park *et al.*, 2001; Ahire and Ravichandran, 2001).

Several researchers have conducted the development of measurement constructs on QM practices (Flynn *et al.*, 1994). For example, Saraph *et al.* (1989) were the first to attempt to explore the measurement of QM practices (Perdomo-Ortiz *et al.*, 2006). Their motivation fuelled due to a lack of a systematic attempt to organize a set of QM practices and develop measures of the overall QM efforts in the QM literature. Using a survey of 162 general managers and quality managers, they proposed eight critical factors of QM: the role of management leadership, the role of the quality department, training, employee relations, quality data and reporting, supplier quality management, product/service design, and process management. Similarly, Flynn *et al.* (1994) argued that QM studies on theory development and measurement failed to yield

conclusive evidence related to validity and reliability. On the basis of a sample of 716 respondents at 42 plants in the United States, they suggested seven key dimensions of QM and scales: top management support, quality information systems, process management, product design, work force management, supplier involvement, and customer involvement. Ahire *et al.* (1996) responded to the lack of studies that scientifically examine constructs to measure the role of QM efforts. In a field study of 371 companies in the automotive components manufacturing industry, they identified 12 QM constructs: top management commitment, customer focus, supplier quality management, design quality management, benchmarking, statistical process control usage, internal quality information usage, employee empowerment, employee involvement, employee training, product quality, and supplier performance.

Although there was no clear agreement on a list of QM practices (Samson and Terziovski, 1999), the efforts to develop a set of QM practices provided a theoretical foundation to scientifically connect traditional QM philosophies with practical activities. Researchers believed that the successful adoption of QM philosophies can be attributed to the strong support of a set of QM practices (Ravichandran, 2007; Nair, 2006). Similarly, the sets of QM practices discussed were broadly cited in the literature (e.g., Perdomo-Ortiz *et al.* 2006) and frequently used in replication studies (e.g., Kaynak, 2003). Adopting the methodology used in the previous studies, such as factor analysis, several other studies developed reliable measures (e.g., Samson and Terziovski, 1999). The QM practices were also used to develop criteria for several quality awards, such as the European Foundation for Quality Award (EFQA) and the Malcolm Baldrige National Quality Award (MBNQA) (Sousa and Voss, 2002).

Prior studies further extended the QM practices theory by questioning the extent to which QM practices are correlated with performance. Most empirical studies posited that organizational

performance is accomplished by a set of QM practices (Douglas and Judge, 2001). They focused on examining the impacts of a set of QM practices (input) on performance (output). For example, these studies had the following research questions: Which practices have a direct and positive effect on the performance? Is a degree of implementation of QM practices positively related to the performance? A common finding was that QM practices have a significant and positive effect on operational and quality performance (Zaho *et al.*, 2004). However, most of the studies examined either the impact of QM practices on quality performance or the impact of quality performance on operational/business performance (Sousa and Voss, 2002). In other words, researchers simply focused on testing the correlations of the relationships (Sila and Ebrahimpour, 2005). Although these studies provided insight into possible relationships between QM practices and performance, there were very few studies on theory exploring the interactions among QM practices and the outcomes of QM efforts (Ahire and Ravichandran, 2001; Kaynak, 2003).

The narrow approach to the link between QM practices and performance resulted in several mixed findings or questions of the implementation of QM. For example, some researchers found that the adoption of QM is not always beneficial for all types of organizations. They argued that the failure rate is estimated to be as high as about 60 per cent (Dooyoung *et al.*, 1998). These findings were inconsistent with the argument of quality proponents that all QM practices can be universally applied to yield performance in all kinds of organizations, regardless of the organizational context (Zaho *et al.*, 2004; Park *et al.*, 2001; Ravichandran and Rai, 2000). Further, some empirical studies doubted the effectiveness of mechanistic QM practices (e.g., process management, information and analysis, and product design) on performance (Feng *et al.*, 2006; Hoang *et al.*, 2006). Researchers found that only behavioural QM practices (e.g., leadership, people management, and customer relations) are significantly and positively

associated with performance (Samson and Terziovski, 1999; Powell, 1995). These mixed and unclear findings in the QM literature encouraged academics to pay attention to the interdependence of QM practices (Ahire and Ravichandran, 2001). Studies on the interactions among QM practices are called linkage-focused research in this study.

2.2. Linkage-focused research on QM practices

Linkage-focused research considers the interdependent nature of QM practices. The main objective of this study is to explain why implementing QM is not always sufficient to result in maximum benefits for every company (Kaynak, 2003). The linkage-focused research refers to a study exploring why and how QM practices are interrelated (Ahire and Ravichandran, 2001). Unlike previous studies based on simple analysis approaches (e.g., regression or correlation analyses), the linkage-focused research relies on sophisticated analysis techniques, such as a path analysis (e.g., Flynn *et al.*, 1995) and a partial least square method (e.g., Ravichandran and Rai, 2000) using structural equation modeling. Unfortunately, the literature review indicates that there are a very small number of linkage-focused studies (Sila and Ebrahimpour, 2005). Table 1 summarizes the results of previous studies. The main issues of these studies can be divided into three points: (1) Organizational performance can be achieved through a combination of QM practices; (2) The positive impacts of behavioural QM practices on performance can be mediated by mechanistic QM practices; (3) QM practices can lead to quality, operational, and business results.

Organizational performance can be achieved through a combination of QM practices:

QM researchers view an organization to be a system of interlocking processes. They pay attention to the systems and processes as a source of variation in organizational performance (Soltani *et al.*, 2004). A common view is that competitive advantage can be realized only if organizations handle and manage a combination of a series of practices, not just a few practices separately (Schendel, 1994). This view is, however, not fully supported by some empirical studies. For instance, Powell (1995), in a study conducted on 54 firms in the United States, found that the key to QM performance does not lie in practices such as quality tools or techniques. This finding could lead to the interpretation that organizations do not need to adopt or manage all QM practices. Similarly, Motwani *et al.* (1994, p. 49), in a sample of 73 manufacturing companies, found that “it is not necessary for all the factors to be present to ensure the success of the total quality programme.”

By examining the interaction effects among QM practices, the linkage-focused studies help to identify the reasons for these mixed findings. Although researchers have found different results about the linkages of QM practices, a common finding in the linkage-focused studies is that each QM practice plays its own role in yielding performance. For instance, Ahire and Ravichandran (2001), in a linkage-focused study of 407 plants in the automobile industry, argued that cherry-picking a few QM practices is unlikely to result in significant improvement. They suggested that organizations should implement QM in an integrated fashion including all QM practices. Kaynak (2003) contended that scholars keep in mind the feature of multidimensionality of the QM construct when designing research. These findings are consistent with Douglas and Judge (2001), who found that a reason for the failure of QM is not implementing all key practices.

The positive impacts of behavioural QM practices on performance can be mediated by mechanistic QM practices: The implementation of QM encompasses both mechanistic and behavioural practices (Abruhosa and Moura E Sá, 2008; Rahman, 2004). Earlier studies in the QM literature were rooted in mechanistic practices because the evolution of traditional QM was started from the control of processes and products (Bou and Beltran, 2005). The mechanistic practices – called hard, mechanic, or core practices – aim to ensure that products or services meet customer requirements (Lopez-Mielgo *et al.*, 2009). The mechanistic practices are closely associated with the mechanical/technical/process aspects, such as process management, product/service design, quality data and reporting, benchmarking, and quality tools (Zaho *et al.*, 2004; Hoang *et al.*, 2006; Flynn *et al.*, 1995; Spencer, 1994). However, with a global market facing rapid change and uncertainty, organizations realized the importance of behavioural practices in creating an environment to support mechanistic practices (Rahman, 2004; Flynn *et al.*, 1995; Soltani *et al.*, 2005). The behavioural practices – called soft, organic, or infrastructure practices – are related to behavioural aspects, such as leadership, training, customer relations, workforce management, supplier quality management, and teamwork (Soltani *et al.*, 2008; Rahman, 2004).

From a traditional viewpoint, some argued the necessity of the integrated impact of both aspects (e.g., Feng *et al.*, 2006), while others reported on the importance of only one single aspect: either behavioural practices or mechanistic practices (e.g., Samson and Terziovski, 1999; Perdomo-Ortiz *et al.*, 2006). On this issue, the linkage focused research attempted to explain how behavioural practices interact with mechanistic practices. One finding in the linkage-focused studies is that the mechanistic practices can mediate the effects of the behavioural practices on performance under a QM umbrella (Sousa and Voss, 2002). For example, Zu *et al.* (2008), in an

empirical study of 226 U.S. manufacturing plants, examined the relationships among behavioural practices, mechanistic practices, and performance. They found that the behavioural practices have an impact on performance through the mechanistic practices. They also proved that there are significant and positive relationships between the behavioural and mechanistic practices, such as between workforce management and product/service design. Similarly, Flynn *et al.* (1995), in an empirical study based on a survey of 42 manufacturing plants in the United States, concluded that many behavioural practices are significantly related to mechanistic practices by providing significant paths, such as between top management support and product design process and between work attitude and process flow management.

QM practices can lead to quality, operational, and business results: In the linkage-focused studies, researchers concentrate on examining operational and financial performance. The approach is consistent with majority view of performance in the QM literature that classifies organizational performance into three streams: quality, operational, and business performance (Zaho *et al.*, 2004; Park *et al.*, 2001). For example, some linkage-focused studies tested the relationship between QM practices and a single performance, such as quality performance (e.g., Ravichandran and Rai, 2000; Ahire and Ravichandran, 2001) or customer satisfaction (e.g., Anderson *et al.*, 1995; Rungtusanatham *et al.*, 1998). Others examined multiple performances, such as operational and financial performance (e.g., Kaynak, 2003; Sila and Ebrahimpour, 2005; Zu *et al.*, 2008; Flynn *et al.*, 1995). Existent studies generally agree that QM practices improve quality and the operational and business performance. Further, linkage-focused researchers found that a few QM practices (e.g., process management and product/service design) positively and directly influence performance. For instance, Flynn *et al.* (1995) concluded that two practices – the product design process and process flow management – directly influence quality

performance. Similarly, Ravichandran and Rai (2000) found that one practice – process management efficacy – makes a direct impact on quality performance. Kaynak (2003) also proved that three practices – product/service design, process management, and supplier quality management – have direct impacts on inventory and quality performance.

In sum, the linkage-focused studies contribute to the development of QM theories by identifying what interactions among QM practices are crucial and which QM practices influence performance directly or indirectly. However, reviewing the linkage-focused studies gives rise to a question: What other performance through the implementation of QM should be evaluated? It can be argued that the impacts of QM practices can be available not only in operational performance but also in innovation. There is little attention paid to the relationships between QM practices and innovation in the linkage-focused study. This narrow view of the impacts of QM practices is one of the main obstacles that hinders the expansion of research scopes into QM practices. The lack of theories of a link between innovation and QM also limits our understanding of how quality-oriented organizations can survive in an innovation intensive environment.

Table 1. Relationships among QM practices identified in empirical studies

Studies	Data Sources, QM Practices, and Dependent Variables	Significant and Direct Relationships between QM Practices	No Significant and Direct Relationships between QM Practices
Flynn <i>et al.</i> (1995)	42 manufacturing plants in the United States. QM Practices (8): process flow management, product design process, statistical control/feedback, customer relationship, supplier relationship, work attitude, workforce management, and top management support.	Top management support → Customer relationship Top management support → Supplier relationship Top management support → Workforce management Top management support → Work attitudes Top management support → Product design process Workforce management → Work attitudes Supplier relationship → Statistical control/feedback Work attitudes → Product design process Product design process → Perceived quality market outcomes Process flow management → Perceived quality market outcomes Perceived quality market outcomes → Competitive advantage Percent of items that pass final inspection → Competitive advantage Process flow management → Percent of items that pass final inspection Statistical control/feedback → Process flow management	Top management support → Process flow management Top management support → Statistical control/feedback Customer relationship → Product design process Work attitudes → Product design process Supplier relationship → Process flow management Workforce management → Process flow management Product design process → Process flow management Product design process → Percent of items that pass final inspection Statistical control/feedback → Perceived quality market outcomes Statistical control/feedback → Percent of items that pass final inspection
Anderson <i>et al.</i> (1995)	41 plants in the United States. QM Practices (6): visionary leadership, internal and external cooperation, learning, process management, continuous improvement, and employee fulfillment Dependent variable (1): customer satisfaction.	Visionary leadership → Internal and external cooperation Visionary leadership → Learning Internal and external cooperation → Process management Process management → Continuous improvement Process management → Employee fulfillment Employee fulfillment → Customer satisfaction	Learning → Process management Continuous improvement → Customer satisfaction
Rungtusanatham <i>et al.</i>	43 plants in Italy. QM Practices (6):	Visionary leadership → Internal and external cooperation Visionary leadership → Learning	Learning → Process management Process management → Employee fulfillment

Studies	Data Sources, QM Practices, and Dependent Variables	Significant and Direct Relationships between QM Practices	No Significant and Direct Relationships between QM Practices
(1998)	visionary leadership, internal and external cooperation, learning, process management, continuous improvement, and employee fulfillment. Dependent variable (1): Customer satisfaction.	Internal and external cooperation → Process management Process management → Continuous improvement Continuous improvement → Customer satisfaction	Employee fulfillment → Customer satisfaction
Ravichandran & Rai (2000)	123 information system (IS) units in the United States. QM Practices (4): top management leadership, a sophisticated management infrastructure, process management efficacy, and stakeholder participation. Dependent variable (1): quality performance.	[Full Model] Top management leadership → Management infrastructure sophistication Management infrastructure sophistication → Process management efficacy Management infrastructure sophistication → Stakeholder participation Stakeholder participation → Process management efficacy Process management efficacy → Quality performance [Decomposed Model] Top management leadership → Quality policy Top management leadership → Rewards Top management leadership → Skill development Quality policy → Process control Quality policy → Fact-based management Rewards → Fact-based management Rewards → Process control Rewards → User participation Rewards → Empowerment Skill development → Empowerment Skill development → User participation Fact-based management → Product quality Fact-based management → Process Efficiency Process control → Product quality Empowerment → Process control	[Full Model] Top management leadership → Process management efficacy Top management leadership → Stakeholder participation Stakeholder participation → Quality performance [Decomposed Model] Quality policy → User participation Quality policy → Empowerment Skill development → Fact-based management Skill development → Process control User participation → Empowerment Process control → Process Efficiency
Ahire &	407 plants in the	Top management leadership → Employee management	Employee management → External cooperation

Studies	Data Sources, QM Practices, and Dependent Variables	Significant and Direct Relationships between QM Practices	No Significant and Direct Relationships between QM Practices
Ravichandran (2001)	automobile parts suppliers industry in the United States and Canada. QM Practices (8): top management leadership, customer focus, employee management, supplier management, internal cooperation, external cooperation, quality-related learning, and core quality improvement. Dependent variables (2): product quality and process quality.	Top management leadership → Supplier quality management Top management leadership → Customer focus Employee management → Internal cooperation Employee management → Learning Supplier quality management → External cooperation Supplier quality management → Learning Customer focus → Learning Internal cooperation → Quality improvement External cooperation → Quality improvement Learning → Quality improvement Quality improvement → Product quality Quality improvement → Process quality	Supplier quality management → Internal cooperation Customer focus → Internal cooperation Customer focus → External cooperation
Kaynak (2003)	214 manufacturing and service firms in the United States. QM Practices (7): management leadership, training, employee relations, quality data and reporting, supplier quality management, product/service design, and process management. Dependent variables (3): financial and market performance, quality performance, inventory management.	Management leadership → Training Management leadership → Employee relations Management leadership → Supplier quality management Management leadership → Product design Training → Employee relations Training → Quality data and reporting Employee relations → Quality data and reporting Quality data and reporting → Supplier quality management Quality data and reporting → Product/service design Quality data and reporting → Process management Supplier quality management → Product/service design Supplier quality management → Process management Supplier quality management → Inventory management performance Product design → Process management Product design → Quality performance Process management → Quality performance Inventory management performance → Quality performance	None
Sila &	220 manufacturing firms in	Leadership → Strategic planning	Strategic planning → Human resource

Studies	Data Sources, QM Practices, and Dependent Variables	Significant and Direct Relationships between QM Practices	No Significant and Direct Relationships between QM Practices
Ebrahimpour (2005)	the United States. QM Practices (7): leadership, strategic planning, customer focus, information and analysis, human resource management, process management, and supplier management. Dependent variable (1): business results.	Leadership → Information and analysis Leadership → Human resource management Leadership → Process management Leadership → Supplier management Leadership → Business results Strategic planning → Customer focus Information and analysis → Strategic planning Information and analysis → Customer focus Information and analysis → Human resource management Information and analysis → Supplier management Human resource management → Process management Process management → Business results	management Strategic planning → Business results Customer focus → Business results Information and analysis → Process management Information and analysis → Business results Human resource management → Customer focus Human resource management → Supplier management Human resource management → Business results Supplier management → Process management Supplier management → Business results Quality information → Product/service design Quality information → Process management Product/service design → Process management
Zu <i>et al.</i> (2008)	226 manufacturing plants in the United States. QM Practices (7): top management support, customer relationship, supplier relationship, workforce management, quality information, product/service design, and process management. Dependent variables (2): quality performance and business performance.	Top management support → Customer relationship Top management support → Supplier relationship Top management support → Workforce management Customer relationship → Quality information Supplier relationship → Product/service design Supplier relationship → Process management Workforce management → Quality information Workforce management → Product/service design Workforce management → Process management Quality information → Supplier relationship Product/service design → Quality performance Process management → Quality performance Quality performance → Business performance	Top management support → Product/service design Top management support → Process management Product/service design → Process management

The findings in Table 1 are based on the hypotheses and the findings of each study.

2.3. Innovation typology

It is essential to understand the types of innovation and their features because a specific type of innovation requires unique and sophisticated responses from an organization (Hurmelinna-Laukkanen *et al.*, 2008). Researchers have developed a typology of innovation in different ways. In the innovation literature, there is either a similar name used for different innovations or the same innovation categorized into different typologies (Garcia and Calantone, 2002). Although previous innovation studies suggested several typologies of innovations, the most prominent type of innovation comprises the following categories: technological versus administrative innovation, incremental versus radical innovation, and product versus process innovation (Cooper, 1998; Zhao, 2005).

2.3.1. Technological versus administrative innovation

Technological innovation is defined as the adoption of new technologies that are integrated into products or processes (Yonghong *et al.*, 2005; Cooper, 1998). Previous studies suggested that technological innovation provides organizations with competitiveness and long-term success in a competitive marketplace (Grover *et al.*, 2007; Leifer *et al.*, 2001; Moors and Vergragt, 2002). Technological innovation is associated with the implementation of technologies to create new markets or to provide new features or functions, not just to solve a technological problem (Green *et al.*, 1995). Technological innovations take place in products and services, while administrative innovations occur in organizational structures and include reward systems, authority patterns, and decision-making processes (Sabet and Klingner, 1993). Using a bottom-

up approach, lower level R&D professionals or technicians are involved in the development of technological innovation (Daft, 1978). The professionals rely on the use of a new tool, device, techniques, or system (Damanpour, 1987). Technological innovations are protected by intellectual property laws, such as patents (Hoffmann and Hegarty, 1993).

Administrative innovation, in contrast, refers to the application of new ideas to improve organizational structures, routines, systems, and processes pertaining to the social structure of an organization (Weerawardena, 2003; Loh and Venkatraman, 1992; Damanpour, 1987; Elenkov *et al.*, 2005; Daft, 1978). Administrative innovation requires considerable set-up costs and entails organizational disruption. This is due to the fact that administrative innovation tends to call for major reassignment of responsibilities and tasks (Teece, 1980). Administrative innovation is triggered by internal needs for structuring and coordination, while technological innovation responds to environmental factors, such as uncertain market conditions or technical knowledge (Gaertner *et al.*, 1984; Daft, 1978). Using a top-down approach, upper-level managers or administrators commit to relevant activities of administrative innovation (Daft, 1978; Ibarra, 1993). Administrative innovation influences basic work activities directly and customers indirectly (Weerawardena, 2003). Administrative innovation is diffused by a specialized agency, such as a consulting firm (Teece, 1980). The literature review, however, indicates that existing innovation studies are biased toward technological innovation (Prajogo and Sohal, 2006; Weerawardena, 2003). There is a lack of research about administrative innovation. Consistent with the views of Claver *et al.* (1998), it can be argued that technological innovation is not always sufficient to meet customer needs and maintain organizational competitiveness in a new global market. It is necessary to explore ways that technological and administrative innovations lead to a competitive advantage (Abrunhosa and Moura E Sá, 2008; Weerawardena, 2003).

2.3.2. Incremental versus radical innovation

For almost 30 years, it has widely been recognized that technological innovation can be split into incremental innovation and radical innovation (Hurmelinna-Laukkanen *et al.*, 2008; Grover *et al.*, 2007; Salavou and Lioukas, 2003; Koberg *et al.*, 2003; Green *et al.*, 1995; Baker and Sinkula, 2007; Broring and Herzog, 2008; Pandey and Sharma, 2009). Both innovations are mutually exclusive, so the less chance for incremental innovation, the more chance for radical innovation (Salavou and Lioukas, 2003). Depending on the degree of innovation, researchers generally distinguish incremental innovation from radical innovation (Weerawardena, 2003). To be more specific, incremental and radical innovations can be distinguished in terms of three key features: a target customer or market (existing vs. new), the level of change (minor vs. major), and the level of risk (low vs. high).

Incremental innovation is defined as minor changes of existing technologies in terms of design, function, price, quantity, and feature (Chandy and Tellis, 1998; Garcia and Calantone, 2002; De Propriis, 2002). Incremental innovation aims to meet the needs of existing customers by refining, broadening, enhancing, and exploiting the current knowledge, skills, and technical trajectory (Gatignon *et al.*, 2002; Broring and Herzog, 2008; Li *et al.*, 2008; Jansen *et al.*, 2006). In a technologically mature market, it is important to manage incremental innovation because continuous improvement of existing technologies helps to identify threats and opportunities related to the shift to a new technology paradigm (Garcia and Calantone, 2002). Lower-level technicians and R&D workers achieve incremental innovation at all stages of a production life cycle (Daft, 1978; Garcia and Calantone, 2002; Ibarra, 1993). Incremental innovation entails a

low level of risk because an organization focuses on modifying or improving existing technologies around radical innovation, not on breaking through an established technology trajectory or direction (Yonghong *et al.*, 2005; Hurmelinna-Laukkanen *et al.*, 2008; Valle and Vázquez-Bustelo, 2009). Less risk taking tends to accompany fewer benefits (Koberg *et al.*, 2003).

Proponents of **radical innovation**, however, doubt the impacts of incremental innovation. They argue that incremental innovation is no longer enough in an intensified, competitive market. Instead, they view radical innovation as a core component in achieving sustainability goals (Moors and Vergragt, 2002). Radical innovation refers to the adoption of new technologies to create a demand unrecognized by customers and markets (Jansen, *et al.*, 2006; Yonghong, *et al.*, 2005; Garcia and Calantone, 2002). Radical innovation is likely to be triggered by market pull or technology push strategies (Li *et al.*, 2008; Moguilnaia *et al.*, 2005). For example, radical innovation provides either an unprecedented feature or a familiar feature that significantly disrupts a trajectory of existing technologies (Leifer *et al.*, 2001). Radical innovation is regarded as competence-destroying because the innovation primarily changes the functions of existing technologies (Teece *et al.*, 1997; Broring and Herzog, 2008). Using a bottom-up approach, lower-level technicians and R&D workers accomplish radical innovation (Daft, 1978). Radical innovation entails great uncertainty and a high level of risk (Moguilnaia *et al.*, 2005). The main reason for this is that there are many technical/market uncertainties, a high degree of complexity, and major changes in the existing technologies (Di Benedetto *et al.*, 2008; Hurmelinna-Laukkanen *et al.*, 2008; Green *et al.*, 1995; Valle and Vázquez-Bustelo, 2009). In this aspect, one study found that radical innovation covers only 10 per cent of all new innovations, whereas the proportion of incremental innovation is about 90 per cent (Rothwell and Gardiner, 1988).

2.3.3. Product versus process innovation

Technological innovation comprises product innovation and process innovation (Damanpour, 1987). Product innovation refers to changes at the end of providing products or services, while process innovation is defined as changes in the way of producing products or services (De Propriis, 2002; Utterback, 1994). The objective of **product innovation** is to meet the needs of customers or the external market. Product innovation is driven by either technological progress or market demand (Salavou and Lioukas, 2003). Product innovation is based on two dimensions: the technological capability dimension and the product capability dimension. The technological capability dimension represents the degree to which the product includes expanding technological capabilities beyond existing capabilities, while the product capability dimension is related to the benefits of products that customers perceive (Veryzer, 1998). Depending on the level of organizational capability at each dimension, product innovation could provide organizations with opportunities to create a new market or to change the balance of power in a competitive market (Herrmann *et al.*, 2007). In terms of the degree of innovation, product innovation can be split into radical product innovation and incremental product innovation (Reichstein and Salter, 2006; Huiban and Bouhsina, 1998). Radical product innovation refers to innovation associated with the introduction of products (or services) that incorporate substantially different technology from existing products, whereas incremental product innovation is defined as innovation related to the introduction of products (or services) that provide new features, improvements, or benefits to the existing technology in the existing market (Herrmann, *et al.*, 2007; Chandy and Tellis, 1998; Valle and Vázquez-Bustelo, 2009).

Process innovation is described as changes in the way that an organization produces products or services (Koberg *et al.*, 2003; Utterback, 1994). Process innovation is associated with the sequences and nature of the production process (De Propriis, 2002). The main purpose of process innovation is to introduce a new element in production materials, machinery, equipment, processes, task specifications, and workflow mechanisms (Damanpour, 1991; Knight, 1967). Examples of process innovation include the implementation of automatic noodle making machines, the introduction of bulk packaging of sleeved products, the introduction of three-dimensional modeling for design, an e-commerce site for sales and services, and the introduction of lean production systems (Reichstein and Salter, 2006). Along this line, process innovation tends to occur more often in large and bureaucratic firms than in small firms. This is because a large firm deals with many input materials and complicated processes with higher economic and social costs (Cooper, 1998). Unlike product innovation, process innovation focuses on improving the productivity and the efficiency of the production activities (Garcia and Calantone, 2002). Process innovation enables organizations to produce large amounts of products or services with limited resources or with higher performance levels (Abrunhosa and Moura E Sá, 2008). Moreover, process innovation can be achieved by a quality-based management approach, namely TQM. This happens because one of the main goals of TQM is to increase productivity and product quality through continual process improvement (Martinez-Costa and Martinez-Lorente, 2008). This argument is supported by prior empirical studies. For example, using data obtained from footwear manufacturing firms, Abrunhosa and Moura E Sá (2008) concluded that quality management practices (e.g., communication, teamwork, and supportive people management practices) have a positive and direct impact on process innovation. In terms of the degree of innovation, process innovation is generally classified into two types: incremental process

innovation and radical process innovation (Reichstein and Salter, 2006, p. 656). Radical process innovation refers to innovation associated with the application of new or significantly improved elements into an organization's production or service operations - input materials, equipment, and work and information flow mechanisms - with the purpose of accomplishing lower costs and/or higher product quality. In contrast, incremental process innovation is identified as innovation associated with the application of minor or incrementally improved elements into an organization's production or service operations – input materials, equipment, and work and information flow mechanisms - with the purpose of accomplishing lower costs and/or higher product quality (Reichstein and Salter, 2006; Huergo and Jaumandreu, 2004; Ettlie, 1983; Gatignon *et al.*, 2002).

In sum, innovation is categorized into technological versus administrative innovation, radical versus incremental innovation, and product versus process innovation. It is vital to understand the different objectives and features of each kind of innovation because a different type of innovation requires different activities and resources from an organization. Table 2 summarizes the key dimensions about the different types of innovation.

Table 2. Comparison of radical, incremental, and administrative innovations

Dimension	Technological Innovation		Administrative Innovation	Sources
	Radical Innovation	Incremental Innovation		
Objective	Create emerging customers and markets by replacing old technologies, disrupting a current technology trajectory, and offering new products/services.	Meet the needs of existing customers by refining, broadening, enhancing, and combining current knowledge, skills, and the technical trajectory.	Improve organizational structures, systems, and administrative processes by adopting new programs or techniques.	Broring and Herzog, 2008; Daft, 1978; Damanpour, 1991; Di Benedetto <i>et al.</i> , 2008; Garcia and Calantone, 2002; Gatignon <i>et al.</i> , 2002; Green <i>et al.</i> , 1995; Hoffman and Hegarty, 1993; Jansen <i>et al.</i> , 2006; Li <i>et al.</i> , 2008; Ravichandran, 2007; Weerawardena, 2003
Level of Change and Subjects of Innovation	Major changes of technological directions with entirely new technologies and products/services; significant changes of the linkage among core components of products/services.	Minor changes of existing product/service components, design, price, function, quantity, and time. Smaller enhancement of products or services around radical innovation.	Major or minor changes of organizational structures, processes, systems, and routines. Examples include new strategic planning or control systems; policies of recruitment; training or rewarding systems; allocation of resources, departments, or positions; and the structuring of tasks.	Broring and Herzog, 2008; Corso <i>et al.</i> , 2007; Daft, 1978; Damanpour, 1987; De Propriis, 2002; Elenkov <i>et al.</i> , 2005; Hoffman and Hegarty, 1993; Loh and Venkatraman, 1992; Moguilnaia <i>et al.</i> , 2005; Moors and Vergragt, 2002; Weerawardena, 2003; Yonghong <i>et al.</i> , 2005
Approach and Organizational Structure	A bottom-up approach conducted by lower-level technicians and R&D workers. Related to organic structures, loosely coupled systems, and improvisation.	A bottom-up approach supported by lower-level technicians and R&D workers. Related to mechanistic structures, control, tightly coupled systems and	A top-down approach initiated by upper-level managers or administrators. Related to mechanistic structures, tightly coupled systems, and centralization.	Daft, 1978; He and Wong, 2004; Ibarra, 1993; Lewin <i>et al.</i> , 1999;

Dimension	Technological Innovation		Administrative Innovation	Sources
	Radical Innovation	Incremental Innovation		
Level of Risk	Achieved in a high level of risk due to technical/market uncertainties, a high degree of complexity, and major changes of technological directions.	Operated in a low risk (or under conditions of greater certainty) due to minor changes of technological components, designs, and knowledge. bureaucracy.	Introduced in both high and low risks, but administrative innovation is rarely amenable to partial adoption or to testing.	Di Benedetto <i>et al.</i> , 2008; Green <i>et al.</i> , 1995; Hurmelinna-Laukkanen <i>et al.</i> , 2008; Leifer <i>et al.</i> , 2001; Moguilnaia <i>et al.</i> , 2005; Moors and Vergragt, 2002; Teece, 1980; Valle and Vázquez-Bustelo, 2009
Outputs	Occurred rarely but led to a competitive advantage; restructured marketplace economics; created entirely new product categories. Caused technological and marketing discontinuities on both a macro and micro level. Destroyed existing competencies. Provided either unprecedented features or familiar features offering significant improvement of existing products/services	Enriched the depth of technology innovation; the breadth of impact is, however, low; incremental innovation does not break through major technology trajectory. Resulted in either technological or marketing discontinuity, but not both, on a micro level. Improved certain dimensions of products or services; expanded brands and product categories; developed existing competencies.	Enhanced organizational structures, routines, and administrative processes that are related to basic work activities. Changed the way to recruit employees, allocate resources, and structure tasks. Added value either directly for a firm or indirectly to its customers.	Baker and Sinkula, 2007; Broring and Herzog, 2008; Cooper, 1998; Damanpour and Evan, 1984; Damanpour, 1987; Garcia and Calantone, 2002; Gatignon <i>et al.</i> , 2002; Herrmann <i>et al.</i> , 2007; Kale and Arditi, 2006; Koberg <i>et al.</i> , 2003; Leifer <i>et al.</i> , 2001; Valle and Vázquez-Bustelo, 2009; Weerawardena, 2003; Yonghong <i>et al.</i> , 2005
Protection of Outputs	Protected by intellectual property law, such as patent; diffused under the technology transfer contract.	Protected by intellectual property law, such as patent; diffused under the technology transfer contract.	Not protected by intellectual property law; diffused by specialized agents (e.g., consulting firms).	Hoffman and Hegarty, 1993

2.4. Impacts of QM practices on innovation

In a rapidly changing environment, high quality is necessary but not sufficient to guarantee success because of the impacts of other features, such as speed, price, and variety (Reimann and Hertz, 1994). The foundation of sustainable competition shifted from quality to innovation (Abrunhosa and Moura E Sá, 2008). Innovation plays a key role in meeting the needs of existing customers or creating a new product or service for emerging customers (Benner and Tushman, 2003). Innovation should be viewed as a core engine to strengthen the extra features and ensure long-term firm success (Leifer *et al.*, 2001). At the organizational level, innovation refers to “the implementation of an internally generated or a borrowed idea – whether pertaining to a product, device, system, process, policy, program, or service – that was new to the organization at the time of adoption” (Damanpour and Evan, 1984, p. 393).

While innovation scholars conceptualized innovation from a variety of perspectives, a large body of studies has been involved in identifying internal determinants of innovation since the late 1960s (Souitaris, 2002). A literature review indicates that internal determinants are related to aspects of behaviour (e.g., leadership) and systems (e.g., control activity). For example, Becheikh *et al.* (2006), in a review study of 108 empirical studies published between 1993 and 2003, concluded that the internal determinants of innovation can be grouped into seven main categories: leadership and management team, organizational strategies, culture, firm structure, control activities, functional assets and strategies, and general characteristics of firms. Similarly, Pandey and Sharma (2009) argued that innovation is affected by a variety of factors, such as people, top management leadership, organizational structure, and culture.

From a positive perspective, QM scholars argue that the internal determinants of innovation are significantly related to a set of QM practices (Perdomo-Ortiz *et al.*, 2006). Behavioural QM practices, for example, could support some determinants of innovation – such as leadership, strategies, and culture – whereas mechanistic QM practices could influence control activities and functional assets and strategies. Similarly, QM scholars considered QM to be a management model for managing innovation (Prajogo and Sohal, 2001). QM researchers assert that examining the relationship between QM and innovation helps employees develop a better understanding of the roles of managerial practices in innovative environments (Prajogo and Sohal, 2001). For instance, as a sequential approach, organizations first identify customer needs based on QM techniques (e.g., the quality function deployment and value stream map) and then produce innovative products or services faster than competitors. Then the organizations standardize relevant processes or systems using QM-based models, such as the ISO 9001 quality management system (Lopez-Mielgo *et al.*, 2009).

From the negative perspective, there is an ongoing debate over the effectiveness of QM on innovation in the context of an uncertain business environment. The main argument is that it is difficult to implement QM in an innovative organization. Studies explain reasons for this argument with two criteria: QM principles (e.g., customer relations) and features of innovative activities (e.g., an empirical science). In terms of QM principles, implementing QM is not appropriate in innovative activities (Prajogo and Sohal, 2001; Perdomo-Ortiz *et al.*, 2006). This is because QM could lead organizations to delay innovation due to the principle of continuous improvement and to be reactive on a short-term basis due to the principle of customer focus. QM also hampers creativity due to the enforcement of formalizations or standards, which leads companies to be imitators or followers rather than innovators or leaders.

With regards to the features of innovative activities, studies conclude that QM does not interact with innovation because innovative activities (e.g., R&D) are different from other activities, such as production or marketing. Montana (1992), for example, suggested three reasons why it is hard to adopt QM in an innovative organization: QM is an experience-oriented model, not an empirical science; technicians or R&D professionals define quality as perfection, not as simply conforming to customer expectations; and quality-based measures are not objective when measuring the performance of quality improvement within R&D. Similarly, May and Pearson (1993) found that innovation is based on individuals, not a quality system; innovative activities are non-repetitive processes; and the cost of quality is not an appropriate measure when evaluating innovation. Vermaercke (2000) noted the following reasons that QM does not interact with innovation: the concept of a customer is vague in innovative efforts; R&D professionals tend to depend on their memory, not a written document; the objectives of an R&D project may change during the process; and R&D professionals believe that customers are not always expert in their field. Unfortunately, by the end of the 1990s, most studies on the impacts of QM on innovation relied on conceptual or case studies (e.g., Lamb and Dale, 1994; Patino, 1997; Debackere *et al.*, 1997; Lovett, 1992). Only a few empirical studies investigated a simple research question: Which QM practice is frequently used in innovative firms (e.g., Miller, 1994; Dellana and Wiebe, 1995)? These studies also made little effort to consider the multidimensionality of QM practices and innovation.

Since the early 2000s, researchers have conducted a limited number of empirical studies on the link between QM and innovation. As Table 3 shows, earlier studies adapted multidimensional constructs to measure organizational QM activities. Most studies used the measurement instrument developed by prior researchers (e.g., Flynn *et al.*, 1994) or criteria of

quality awards, such as the MBNQA and the EFQM awards. Only a few researchers developed their own set of QM practices based on the literature (e.g., Abrunhosa and Moura E Sá, 2008). In terms of the analytical framework, researchers applied a sophisticated analytical framework, such as structural equation modeling (e.g., Feng *et al.*, 2006; Hoang *et al.*, 2006; Prajogo and Sohal, 2004). Only a few researchers used a multiple regression or correlation analysis (e.g., Perdomo-Ortiz *et al.*, 2006; Moura E Sá and Abrunhosa, 2007).

With respect to research findings, existing empirical studies yielded inconsistent results on the effect of QM on innovation. Some studies found that the adoption of QM is positively associated with innovation (Hoang *et al.*, 2006; Martinez-Costa and Martinez-Lorente, 2008), while other studies reported that there is no clear evidence to statistically prove the positive effects of QM on innovation (Prajogo and Sohal, 2004; Singh and Smith, 2004). Furthermore, earlier studies produced different arguments on which QM practice plays a more important role in creating innovation. Some studies argued that only behavioural QM practices – leadership and people management – are closely associated with innovation (e.g., Feng *et al.*, 2006). Others found that not all, but both behavioural and mechanistic QM practices – leadership, people management, process management, and product design – have a positive and direct relationship to innovation (e.g., Hoang *et al.*, 2006; Perdomo-Ortiz *et al.*, 2006). Overall, the literature review indicates that there is a lack of consistent evidence on the impact of QM practices on innovative environments.

This research identifies a few shortcomings of the earlier studies. A major shortcoming is that earlier studies failed to explore how and why a QM practice has an effect on innovation. Most studies examined only the direct relationships between QM practices and innovation. Researchers tend to identify whether the implementation of QM practices has a positive impact

on innovation (e.g., Abrunhosa and Moura E Sá, 2008; Martinez-Costa and Martinez-Lorente, 2008; Hoang *et al.*, 2006) or which QM practice is related to innovation (Moura E Sá and Abrunhosa, 2007; Prajogo and Sohal, 2004). There was little study to test how different QM practices are linked directly or indirectly and why the QM practices consequently influence innovation. Earlier studies answered only “what to do” rather than “how to do.” Little attention was paid to the use of path analysis to analyze interaction effects among QM practices. It can be argued that developing a theory could be accomplished only if a researcher can provide answers about both what to do and how to do it.

Another shortcoming is that researchers were limited to assessing only a few types of innovation. Some studies examined a single type of innovation, such as process innovation (e.g., Abrunhosa and Moura E Sá, 2008) or product innovation (e.g., Prajogo and Sohal, 2004), whereas others explored both process and product innovation (e.g., Feng *et al.*, 2006; Martinez-Costa and Martinez-Lorente, 2008). Looking at the earlier studies, two questions arise: Is it worthwhile to examine QM practices that can influence only product and process innovations? If not, what other types of innovation should be explored to clearly address the impacts of QM on innovation? Limited attention was devoted to identifying and examining various types of innovation. However, testing the multidimensional types of innovation can contribute to the literature by providing a holistic insight into the real impacts of QM on innovation. Therefore, this study deals with the relationship between QM practices and the following dimensions of innovation discussed mainly in the innovation literature: technological vs. administrative, radical vs. incremental, and product vs. process (Zhao, 2005; Santos-Vijande and Álvarez-González, 2007).

To summarize, the relationship between QM and innovation has been empirically investigated since the early 2000s. While researchers made efforts to develop theories from different perspectives, earlier studies failed to examine not only interactions among QM practices but also various types of innovation. Little attempt was made to answer how and why QM practices influence innovation. Most studies examined only narrow aspects of innovation, namely product or process innovation. The lack of theory development on the issue limits our understanding of how QM practices consistently lead to innovation.

Table 3. Empirical studies on the relationship between QM practices and innovation

Studies	Data sources	Analytical approaches	Independent variables	Mediating or Control variables	Dependent variables	Main findings
Prajogo and Sohal (2004)	194 manufacturing and non-manufacturing firms in Australia	Structural equation modeling	QM mechanistic elements (4): customer focus, information & analysis, people management, and process management. QM organic elements (2): leadership and strategic planning.	No variable	Product quality (4): reliability, performance, durability, and conformance to specification. Product innovation (5): the # of innovations, the speed of innovation, the level of innovativeness, latest technology used, and being the “first” in the market.	No significant relationship between TQM practices and organizational performance (Product innovation and quality). No supporting evidence to suggest that organizations should emphasize certain practices when pursuing different strategic performances.
Singh and Smith (2004)	418 manufacturing firms in Australia	Structural equation modeling	QM practices (7): top management leadership, customer focus, employee relations, relationship with suppliers, competitors, communication/information systems, and product/process management.	No variable	Technological innovation (4): commercialized processes/products/services, the rate of innovation of new processes, the rate of introduction of new products/services, and developed world-class techniques/technologies.	No firm link between QM practices and innovation.
Feng <i>et al.</i> (2006)	252 firms: 194 from Australia and 58 from Singapore	Structural equation modeling	QM practices (6): leadership, strategic planning, customer focus, information & analysis, people management, and	No variable	Process quality and product innovation (5): the number of innovations, the speed of innovation, the level of innovativeness	Behavioral practices (e.g., leadership and people management) are related to innovation.

Studies	Data sources	Analytical approaches	Independent variables	Mediating or Control variables	Dependent variables	Main findings
			process management.		(novelty or newness), latest technology used, and being the “first” in the market.	
Hoang <i>et al.</i> (2006)	204 manufacturing and service firms in Vietnam	Structural equation modeling	QM practices (11): top management commitment, employee involvement, employee empowerment, education & training, teamwork, customer focus, process management, information & analysis system, strategic planning, open organization, and service culture	No variable	Innovation (2): the actual innovation output (# of new products and the share of the current annual turnover) and the level of newness (e.g., entirely new product or new service and use of new materials or intermediate products)	Positive and significant relationship between QM practices and innovation. Not all QM practices enhance innovation. Only three variables (leadership and people management, process and strategic management, and open organization) showed a positive impact on innovation. Education and training, while showing a positive effect on the number of new products and services, had a negative relationship with the level of newness.
Perdomo-Ortiz <i>et al.</i> (2006)	102 machinery and instruments firms in Spain	Multiple regression analysis	QM practices (6): management support, information for quality, process management, product design, human resource management, and relationship with customer and suppliers.	Control variables, firm size, belonging to a business group, the real or foreseen implementation of technological audits.	Business innovation capability (6): planning and commitment on the part of management, behavior and integration, projects, knowledge and skills, information and communication, and external environment.	Positive and significant relationship between QM practices and business innovation capability. Three QM practices (process management, product design, and human resource management) are more important than other variables → It means that the mechanistic QM practices also are highly significant in the building of business innovation capability (BIC).

Studies	Data sources	Analytical approaches	Independent variables	Mediating or Control variables	Dependent variables	Main findings
Moura E Sá and Abrunhosa (2007)	16 footwear manufacturing firms in Portugal	Correlation analysis	QM principles (5): autonomy, internal communication, consultation, formalization, and qualitative flexibility.	No variable	Technological innovation (3): mean number of innovations adopted over time (MNI), mean time of adoption of innovations (MTI), and the consistency of the time of adoption of innovations (CTI).	Evidence of the importance of size is very slight. No significant effects from belonging to a business group. The implementation of technological audits in firms significantly explains the presence of innovative practices. No significant relationships between QM practices and technological innovation. Negative relationship between formalization and technological innovation.
Santos-Vijande and Álvarez-González (2007)	93 ISO 9000 certified firms (manufacturing and service) in Spain	Structural equation modeling	QM practices (5): leadership, people, policy & strategy, processes & resources, and partnership.	Mediating variable. Innovativeness: innovation proposals are welcome; management seeks innovative ideas; innovation is not perceived as too risky; people are not penalized for new ideas; managers promote innovative ideas. Moderating variable: Market	Technical innovation (2): # of product and service innovations and # of production processes or service operations innovations. Administrative innovation (2): # of managerial innovations and # of marketing innovations in the last five years	No direct and positive relationship between QM practices and technical innovation. No direct and positive relationship between innovativeness and administrative innovation. Positive and direct relationship between innovativeness and technical innovation → the mediating role of innovativeness is required to achieve technical innovation. Positive and direct

Studies	Data sources	Analytical approaches	Independent variables	Mediating or Control variables	Dependent variables	Main findings
Abrunhosa and Moura E Sá (2008)	20 footwear manufacturing firms in Portugal	Multiple regression analysis	QM principles (5): autonomy, communication, consultation, qualitative flexibility, and supportive people management practices.	No variable	Process-based technological innovation (2): mean number of innovations adopted over time and mean time of adoption of innovations.	relationship between QM practices and administrative innovations. The effect of QM on innovation is moderated by market turbulence Positive and significant relationship between three QM practices (communication, teamwork, and supportive people management practices) and technological innovation. No significant relationship between two QM practices (autonomy and consultation) and technological innovation.
Martinez-Costa and Martinez-Lorente (2008)	451 manufacturing and non-manufacturing firms in Spain	Structural equation modeling	QM practices (8): continuous improvement activity, use of tools for quality improvement in teamwork, statistical process control, supplier selection based on quality criteria, employee training, leadership, total preventive maintenance, and meeting with customers.	Mediating variables. Product innovation (3): # of new products, pioneering disposition to introduce new products, and # of hours, teams and training spent to obtain new products. Process innovation (3): # of changes in the process, pioneering disposition to introduce new processes, and fast	Company results (4): productivity, market share, profitability, and product quality.	Positive and significant relationship between QM practices and product and process innovation. Positive and significant relationship between the innovation and company performance. Positive and significant relationship between QM practices and company performance.

Studies	Data sources	Analytical approaches	Independent variables	Mediating or Control variables	Dependent variables	Main findings
Prajogo and Hong (2008)	130 R&D divisions of manufacturing firms in South Korea	Structural equation modeling	QM practices (6): leadership, strategic planning, customer focus, information & analysis, people management, and process management.	response to the new processes introduced by other firms. No variable	Process quality (4): the performance of products, conformance to specifications, reliability, and durability of products. Product innovation (5): the level of newness, the use of latest technology, the speed of product development, the # of new products, and early market entrants.	Positive and significant relationship between QM practices and both product quality and product innovation. QM as a set of generic principles can be adapted in environments other than manufacturing or production areas

3. Theoretical framework and hypotheses

This section first provides a theoretical framework to address the relationships between QM practices and innovation. Then it develops research hypotheses based on the literature review.

3.1. Theoretical framework

The proposed framework (Figure 1) is developed to explore how and why QM practices are correlated with innovation. The framework reflects a core philosophy of QM: the entire organization is a system of interlocking processes (Soltani *et al.*, 2004). The framework posits that the interaction effects and interrelationships among QM practices result in innovation (Nair, 2006). In terms of *independent variables*, this study utilizes a set of QM practices developed by Saraph *et al.* (1989).

The set of QM practices by Saraph *et al.* (1989) is widely cited in QM studies (Nair, 2006; Samson and Terziovski, 1999; Mehra *et al.*, 2001; Sila and Ebrahimpour, 2005). The set of practices is often examined as one of the solid set of practices in replication studies (e.g., Kaynak, 2003; Quazi *et al.*, 1998; Ho *et al.*, 2001; Motwani *et al.*, 1994; Kaynak and Hartley, 2005). This study, however, customizes the set of QM practices of Saraph *et al.* (1989). This is because a theory could be developed by integrating solid but old theories and recent theories. For instance, unlike the original set of practices proposed by Saraph *et al.* (1989), a set of QM practices in this study excludes one practice: the role of the quality department. The literature

review shows that many organizations do not have a separate quality department (Kaynak, 2003). Instead, a new practice (customer relations) is added in this study because customer relations practices are broadly tested and recognized as a representative QM practice in many empirical studies (Brah *et al.*, 2000; Powell, 1995; Mehra *et al.*, 2001; Sila, 2007; Douglas and Judge, 2001; Zu *et al.*, 2008; Samson and Terziovski, 1999). Thus, eight QM practices, such as management leadership and customer relations, are examined in this study.

With respects to *a dependent variable*, this study implements a comprehensive typology of innovation that is the most prominent classification in the innovation literature (Cooper, 1998; Zhao, 2005). This study examines five different types of innovation: radical product, radical process, incremental product, incremental process, and administrative innovation. In earlier studies, the innovation construct was operationalized in terms of a single item (product or process) or two items (product and process), not these multiple types of innovation. However, examining multiple aspects of innovation is essential to contribute to the development of the QM literature. This attempt will be helpful to understand the real impacts of QM practices on innovation and to interpret why earlier studies produced mixed findings. Furthermore, moderator effects between QM practices and innovation are examined. This study assumes that the intensity of the relationship between QM practices and innovation is moderated by the following factors: firm size, the duration of QM adoption, structural control, structural exploration, and industry.

To design *causal relationships* among QM practices, this study adopts a research model that was empirically examined by Kaynak (2003, see Appendix A). The causal model of Kaynak (2003) provides a foundation to develop hypotheses for this study. The proposed model in this study is, however, different from the model by Kaynak (2003) in the following three aspects. First, this study develops its own hypotheses associated with a dependent variable based on the

innovation literature. Kaynak (2003) explored only the relationship between QM practices and traditional performances (quality, inventory, and financial and market performance). Unlike Kaynak's model (2003), the proposed model in this study examines the link between QM practices and five different types of innovation. Second, this study adds a hypothesis pertaining to a variable of QM practices, namely customer relation. Specifically, the proposed framework examines a link between employee relations, and quality data and reporting. The model of Kaynak (2003) did not encompass this link. On the other hand, the earlier studies widely advocated and proved the effects of customer relations (Flynn *et al.*, 1995; Rungtusanatham *et al.*, 1998; Ravichandran and Rai, 2000; Sila and Ebrahimpour, 2005; Zu *et al.*, 2008). Third, in contrast to the model by Kaynak (2003), this study groups QM practices into two blocks: behavioural QM practices and mechanistic QM practices. This approach was suggested by Flynn *et al.* (1995), Ahire and Ravichandran (2001), and Zu *et al.* (2008). In this study, the behavioural practices encompass five components: management leadership, training, employee relations, supplier quality management, and customer relations (Flynn *et al.*, 1995; Soltani *et al.*, 2008; Rahman, 2004), while the mechanistic practices are related to quality data and reporting, process management, and product and service design (Hoang *et al.*, 2006; Rahman, 2004; Lopez-Mielgo, *et al.*, 2009; Flynn *et al.*, 1995).

The **basic premise** of the framework holds that the impacts of each construct are based on the sequential nature of organizational transformation proposed by Ahire and Ravichandran (2001). This nature means that there is a cumulative effect of one practice on another practice. In addition, the impacts of a practice still exist along with other practices, while the practice already influenced other practices. This is because organizations continue to make an effort to find the impacts of QM practices. For example, management leadership influences training and employee

relations. Both training and employee relations directly impact quality data and reporting. Quality and reporting, in turn, have an effect on process management that, consequently, influences innovation. However, the roles of the practices (e.g., management leadership) exist and should be emphasized continuously. This is mainly attributed to the fact that the practices are crucial determinants of other practices, such as training and employee relations. This is consistent with the fact that QM requires never-ending organizational and employee commitment and time (Yusuf *et al.*, 2007). The remainder of this section discusses definitions of each of the framework's constructs, followed by the description of the hypotheses.

Figure 1. A priori theoretical framework

3.2. Management leadership

Management leadership refers to the extent to which top management establishes quality goals and strategies, allocates resources, participates in quality improvement efforts, and evaluates quality performance (Saraph *et al.*, 1989; Anderson *et al.*, 1994). It is essential to examine the impacts of management leadership along with other QM practices. The commitment of top management is generally a starting point for adopting QM and enhancing performance by affecting other QM practices (Ahir and Ravichandran, 2001; Sila and Ebrahimpour, 2005). The efforts of top management consequently contribute to creating a sophisticated QM infrastructure and driving changes across organizations (Ravichandran and Rai, 2000). It is impossible to build an effective environment for QM and produce performance of QM practices without strong top management support (Flynn *et al.*, 1995). This study tests management leadership as an important antecedent of both other QM practices and innovation.

The commitment to QM can come only from the top management responsible for driving changes (Summers, 2009). Top management should establish a learning-intensive environment for the adoption of QM by ensuring adequate financial support for training and monitoring performance through training (Mehra *et al.*, 2001; Zu *et al.*, 2008). They know that the development of workforce skills and knowledge is a minimum requirement to achieve a better job and leads to a better understanding of employee roles (Besterfield *et al.*, 2003). As a workforce motivator, top management also makes an effort to communicate with, motivate, and empower employees throughout the organization (Evans and Lindsay, 2008). It is imperative that top management makes individual employee knowledge and organizational goals consistent

(Goetsch and Davis, 2006). Top management has to trust in the performance of employees, rather than trying to control employees (Besterfield *et al.*, 2003). Distributing responsibilities and accountabilities enables employees to pay attention to organizational quality goals.

Top management establishes a long-term collaboration with suppliers. The role of suppliers is very important when obtaining high quality materials and leveraging unique knowhow and expertise (Lemke *et al.*, 2003). Top management considers high quality to be the most important criterion when selecting a supplier. This is because top management understands that organizational competitiveness can be increased only if an organization relies on high quality materials, not cheap ones (Besterfield *et al.*, 2003). Moreover, improving customer satisfaction can be accomplished by the commitment of top management. Top management outlines quality goals and plans based on customer satisfaction. Employees consider the goals and plans to be a baseline whenever they prioritize resources and necessary actions (Eng and Yusof, 2003). Next, using the quality-based principles, top management can motivate employees to be involved in design processes, develop teamwork, and enhance productivity (Saraph *et al.*, 1989). It is top management that creates a focus on QM so that all affected departments are involved and that works out current or potential conflicts among departments.

Similarly, existing empirical studies broadly support direct and positive links between the following: management leadership and training (Anderson *et al.*, 1995; Ravichandran and Rai, 2000; Kaynak, 2003), management leadership and employee relations (Flynn *et al.*, 1995; Anderson *et al.*, 1995; Ravichandran and Rai, 2000; Ahire and Ravichandran, 2001; Kaynak, 2003; Sila and Ebrahimpour, 2005; Zu *et al.*, 2008), management leadership and supplier quality management (Flynn *et al.*, 1995; Ahire and Ravichandran, 2001; Kaynak, 2003; Sila and Ebrahimpour, 2005; Zu *et al.*, 2008), management leadership and customer relations (Flynn *et*

al., 1995; Zu *et al.*, 2008; Ahire and Ravichandran, 2001), and management leadership and product design (Flynn *et al.*, 1995; Kaynak, 2003). In light of this information it is logical to expect that management leadership influences five QM practices: training, employee relations, supplier quality management, customer relations, and product design. Therefore, the previous discussion leads to the following hypotheses:

H 1: **Management leadership** will be positively associated with training.

H 2: **Management leadership** will be positively associated with employee relations.

H 3: **Management leadership** will be positively associated with supplier quality management.

H 4: **Management leadership** will be positively associated with customer relations.

H 5: **Management leadership** will be positively associated with product/service design.

3.3. Training

Training is identified as the extent to which an organization provides employees with knowledge related to statistics, job-related skills, and quality-oriented information, such as quality techniques. Training is considered to be a basic factor in the success of QM implementation (Bou and Beltran, 2005; Yusuf *et al.*, 2007). Unless employees know how to implement concepts or techniques of QM in their jobs, employees might be resistant and not committed to change, instead of giving positive impacts and the effects of synergy to change (Soltani *et al.*, 2005). A well-trained employee tends to work efficiently and effectively to

improve performance (Zu *et al.*, 2008). It should be noted that an organization starts a training program by highlighting how QM can directly affect individual jobs and customer satisfaction (Summers, 2009). This approach helps employees to be involved in training proactively, taking steps to improve their weaknesses. Sources of training comprise in-house training, external training, and a combination of in-house and external (Goetsch and Davis, 2006). Depending on the objectives or contexts of training, organizations should select a type of training to improve productivity and performance.

Appropriate training provides several benefits, such as improving teamwork, decreasing errors or turnover rate, increasing flexibility, and establishing harmonious employee relations (Goetsch and Davis, 2006). In particular, training has a direct impact on the employees' way of working (Mehra *et al.*, 2001). For example, training allows employees to view organizational systems as interlinked processes (Ravichandran and Rai, 2000). Employees recognize that they should build strong teamwork to work in the system and to manipulate individual perspectives. Furthermore, employees learn how to implement quality techniques (e.g., statistical process control, value flow chart, and benchmarking) and quality principles (e.g., fact-based approach, process approach, and customer relations). Without training, it is impossible for employees to measure performance, record results, analyze data, and monitor improvement efforts (Kaynak, 2003). Extant empirical evidence supports this discussion on the relationships among training, employee relations, and quality data/reporting. For instance, Ravichandran and Rai (2000), in an empirical study of 123 information system units, concluded that the development of employee skills significantly influences employee empowerment. Similarly, Kayank (2003), in a study of 214 manufacturing and service industries, found that training is directly related to both employee relations, and quality data and reporting. Therefore, the following hypotheses are proposed:

H 6: **Training** will be positively associated with quality data and reporting.

H 7: **Training** will be positively associated with employee relations.

3.4. Employee relations

Employee relations in this context are defined as the extent to which employees are involved in quality efforts, participate in quality decisions, have responsibilities for quality, recognize superior quality performance, handle quality issues, and improve the general awareness about quality (Saraph *et al.*, 1989). The success of QM implementation can be assured only if responsibility for quality is extended to all employees and all departments in an organization (Bou and Beltran, 2005; Eng and Yusof, 2003). Employees are the most important component in accomplishing success (Evans and Lindsay, 2008). An employee should understand how his or her job fits into the organizational goals and strategies to improve performance (Summers, 2009). In this line, employee relations should focus on encouraging employees to be involved in quality efforts and to be motivated and empowered. Further, organizations should know the crucial difference between involvement and empowerment. Involved employees are required to provide input but are not given ownership of their jobs; empowered employees are given ownership of their jobs and working processes (Goetsch and Davis, 2006). Creating a nonthreatening and creative environment helps to nurture empowered employees (Besterfield *et al.*, 2003). This environment also facilitates the cross-functional problem solving and teamwork that are central to handling change (Yusuf *et al.*, 2007).

Empowered employees demonstrate a strong sense of ownership (Mehra *et al.*, 2001). They understand the ways that products/services are designed and improved, and they may discover other ways that products/services could increase customer satisfaction (Summers, 2009). Employees struggle to learn quality tools and techniques, such as check sheets, flow charts, and statistical process control. It is a common view that an empowered employee effectively collects information, and measures and analyzes data (Kaynak, 2003; Zu *et al.*, 2008). This is because the employee clearly understands the principle of continuing improvement. Further, an employee plays a key role in identifying, maintaining, and enhancing processes. An employee tries to implement quality improvement approaches, such as plan-do-check-act (PDCA). Various processes are also periodically audited by internal professionals, such as an auditor of the ISO 9001 quality management system. Using a team problem-solving approach and continual improvement, employees can improve product/service design (Choi and Eboch, 1998; Zu *et al.*, 2008; Evans and Lindsay, 2008). Along the same line, empirical studies provided positive evidence about the following relationships: between employee relations and quality data/reporting (Ho *et al.*, 2001; Flynn *et al.*, 1995; Kaynak, 2003; Zu *et al.*, 2008); employee relations and product/service design (Zu *et al.*, 2008); and employee relations and process management (Zu *et al.*, 2008; Flynn *et al.*, 1995; Rungtusanatham *et al.*, 1998; Ravichandran and Rai, 2000; Sila and Ebrahimpour, 2005). Therefore, this discussion leads to the following hypotheses:

H 8: Employee relations will be positively associated with quality data and reporting.

H 9: Employee relations will be positively associated with product/service design.

H 10: **Employee relations** will be positively associated with process management.

3.5. Supplier quality management

Supplier quality management is defined as the extent to which an organization depends on fewer suppliers, is interdependent with suppliers, emphasizes quality rather than price in the purchasing policy, and supports suppliers in product development (Saraph *et al.*, 1989). Supplier quality management is recognized as one of the key elements because suppliers largely affect the overall cost and quality of products or services. For example, 60% of the cost of goods sold in 2000 was used to purchase raw materials, components, or goods (Besterfield *et al.*, 2003). Leading companies struggle to establish a strong network with a small number of core suppliers (Summers, 2009). Companies understand that the strong partnership can be established only if they concentrate on critical success factors, such as trust, communication, conflict resolution techniques, commitment, and coordination (Mohr and Spekman, 1994; Brinkerhoff, 2002; Lambert *et al.*, 2004; Maloni and Benton, 1997). Moreover, companies should not select suppliers based on the lowest bidder. This is because suppliers who bid low will find ways to reduce their losses, resulting in poor quality (Goetsch and Davis, 2006).

Supplier quality management has a direct impact on product/service design. In a long-term, successful partnership, suppliers are seriously involved in the buyers' product design teams where they offer key information about prospective components or materials (Flynn *et al.*, 1995; Kaynak, 2003). Buyers and suppliers work together as partners and share information to maximize quality performance (Besterfield *et al.*, 2003). Through this involvement, buyers take

opportunities to identify customer needs, to standardize components, and to reduce redesigns (Zu *et al.*, 2008; Flynn *et al.*, 1995). Furthermore, supplier quality management helps to improve organizational processes. With the introduction of the just-in-time (JIT) approach, buyers ask suppliers to provide high quality, small quantities of materials and frequent delivery. It is necessary for suppliers to provide exceptional quality and reduced setup times (Mehra *et al.*, 2001; Besterfield *et al.*, 2003). These efforts enable buyers to minimize not only variance in processes or components but also inventory costs (Kaynak, 2003). In light of this discussion, existing empirical studies support the following relationships: between supplier quality management and product/service design (Flynn *et al.*, 1995; Kaynak, 2003; Zu *et al.*, 2008) and supplier quality management and process management (Kaynak, 2003; Zu *et al.*, 2008; Flynn *et al.*, 1995). Therefore, the following hypotheses are proposed:

H 11: Supplier quality management will be positively associated with product/service design.

H 12: Supplier quality management will be positively associated with process management.

3.6. Customer relations

Customer relations are defined as the extent to which an organization emphasizes understanding customer needs (Ahire and Ravichandran, 2001). Examining the relationship between customer relations and other QM practices is important because customers are considered to be the most valuable asset to any organization (Besterfield *et al.*, 2003; Ahire and Ravichandran, 2001). Organizations ensure that they provide a product or a service that

customers really need and continually check to see if their product or service is reactive to current and emerging customer requirements (Yusuf *et al.*, 2007; Samson and Terziovski, 1999). To accomplish these goals, the organizations tend to invite customers and show them production procedures, encourage customer feedback about their products or services, and offer information about emerging products (Flynn *et al.*, 1995). Existing empirical studies found that customer relations are positively related to quality and reporting. For example, using data in 226 manufacturing plants in the United States, Zu *et al.* (2008) argued that a close relationship with customers facilitates the collection and use of data. This is because managers can easily collect first-hand information or data when they have a close relationship with customers. It is possible to expect that customer relations influence quality data and reporting. Therefore, this discussion leads to the following hypothesis:

H 13: Customer relations will be positively associated with quality data and reporting.

3.7. Quality data and reporting

Quality data and reporting is defined as the extent to which an organization uses quality data, uses feedback of quality data to employees for problem solving, measures quality on a regular basis, and evaluates employees based on quality performance (Saraph *et al.*, 1989). Organizations commonly use quality data to maintain customer relations, to drive excellence, and to continue to enhance performance (Samson and Terziovski, 1999). Managing quality data is based on a key principle of QM: in the factual approach effective decisions should be

grounded on the analysis of data and information (ISO, 2000). All employees, not just a quality control team, must be involved in activities to consistently collect data, to accurately analyze data, and to evaluate relevant results in a timely fashion (Yusuf *et al.*, 2007; Zu *et al.*, 2008). This is because all employees, as process owners in their jobs, are responsible for systematically managing data (Evans and Lindsay, 2008). It is helpful for organizations to use various QM techniques, such as statistical process control and Pareto charts (Nair, 2006).

Quality data has a positive impact on supplier quality management. For example, employees can use quality data when selecting a supplier, developing a specification, and assessing the performance of suppliers (Kaynak, 2003). Managing quality data enables companies to develop a set of performance indicators to assess a supplier's capability (Evans and Lindsay, 2008). Further, in a product and service design stage, it is essential for organizations to implement quality data to develop customer-based products and prevent redesign. This is due to the fact that the design processes tend to require much information and a wide range of data (Flynn *et al.*, 1995). It is possible for employees to appropriately analyze and use quality data collected from all departments, such as marketing and R&D (Zu *et al.*, 2008). Moreover, another benefit of quality data is to help employees when modifying and improving processes (Kaynak, 2003). This is because quality data is constantly updated and revised, resulting in the creation of a new process or the improvement of an old process. Next, earlier studies showed that quality data can play a key role in achieving innovation. For instance, Miller (1995), in an empirical study of 45 large multinational firms, concluded that managing quality data is one of the most important QM practices that can be applicable to innovative activities. Along the same line, Mathur-De Vré (2000) found that QM practices help to develop confidence in the credibility and reliability of all the scientific data. Accordingly, Mathur-De Vré (2000) argued that it is

important to manage the data to yield innovation – especially when multiple parties are involved in a single innovation project. Similarly, existing empirical studies supported relationships between the following: quality data/reporting and supplier quality management (Kaynak, 2003; Sila and Ebrahimpour, 2005; Zu *et al.*, 2008), quality data/reporting and product/service design (Kaynak, 2003), and quality data/reporting and process management (Ravichandran and Rai, 2000; Kaynak, 2003). Therefore, the following hypotheses are proposed:

- H 14: **Quality data and reporting** will be positively associated with supplier quality management.
- H 15: **Quality data and reporting** will be positively associated with product and service design.
- H 16: **Quality data and reporting** will be positively associated with process management.
- H 17: **Quality data and reporting** will be positively associated with radical product innovation.
- H 18: **Quality data and reporting** will be positively associated with incremental product innovation.
- H 19: **Quality data and reporting** will be positively associated with radical process innovation.
- H 20: **Quality data and reporting** will be positively associated with incremental process innovation.
- H 21: **Quality data and reporting** will be positively associated with administrative innovation.

3.8. Product/service design

Product/service design is defined as the extent to which: all departments are involved in design reviews; an organization emphasizes productivity; an organization makes specifications clear; an organization highlights quality, not roll-out schedule; and an organization avoids frequent redesigns (Saraph *et al.*, 1989). Product/service design aims at increasing design quality and guaranteeing design for manufacturability (Nair, 2006; Flynn *et al.*, 1995). Design quality leads to standardizing components, simplifying designs, and incorporating customer needs in design processes (Zu *et al.*, 2008). Organizations should encourage constant communication among customers, design engineers, and manufacturers (Flynn *et al.*, 1995). These efforts translate what employees understand into specifications to appropriately design a product/service.

Earlier studies noted that there is a positive relationship between the product/service design and process management. A well-designed product/service is characterized by fewer and standardized components. These features result in efficient process management because employees can reduce process variance and process complexity (Kaynak 2003; Ahire and Dreyfus, 2000; Flynn *et al.*, 1995). Product/service design allows employees to reduce unnecessary changes, to prevent quality problems, and to minimize failure rates (Zu *et al.*, 2008). Empirical studies also indicate that product/service design can facilitate process management. For example, Ahire and Dreyfus (2000), in a study of 418 manufacturing plants from multiple industries, found that design management has a strong and positive effect on process quality management. Similarly, using data from 214 manufacturing and service industries in the United

States, Kaynak (2003) provided evidence to support the relationship between product/service design and process management. Therefore, this discussion leads to the following hypothesis:

H 22: Product/service design will be positively associated with process management.

3.9. Process management

Process management is defined as the extent to which: an organization clarifies process ownership, boundaries, and steps; an organization relies on less inspection; employees use quality techniques and automation; employees use fool-proof process design; and employees conduct self-inspection, preventive maintenance, and automated testing (Saraph *et al.*, 1989). QM scholars highlighted that an organization is a set of interlinked processes. They believe that organizational performance can be improved through careful attention to developing these interlinked processes (Samson and Terziovski, 1999; Nair, 2006). This perspective is a foundation to motivate organizations to make an effort to develop processes. From an operational perspective, process management leads to the elimination of slack and of errors, and a reduction in variation (Yusuf *et al.*, 2007; Choi and Eboch, 1998). From an organizational perspective, process management has a positive effect on improving quality, increasing output uniformity, and increasing aggregate performance (Ahire and Ravichandran, 2001; Flynn *et al.*, 1995; Kaynak, 2003; Nair, 2006; Ravichandaran and Rai, 2000).

Empirical studies support the relationship between process management and innovation. For instance, Hoang *et al.* (2006), in an empirical study of 204 manufacturing and service firms,

found that process management is positively related to innovation, such as the number of new products and the number of new functional solutions. Similarly, Perdomo-Ortiz *et al.* (2006), in an empirical study of 102 machinery and instruments firms, concluded that process management has a greater explanatory power over business innovation capability. Perdomo-Ortiz *et al.* (2006) underlined that process management outstandingly influences innovation capability. Prajogo and Hong (2008), in a study of 130 R&D divisions of manufacturing firms, found that process management is directly and positively related to product innovation. Therefore, the following hypotheses are proposed:

H 23: **Process management** will be positively associated with radical product innovation.

H 24: **Process management** will be positively associated with incremental product innovation.

H 25: **Process management** will be positively associated with radical process innovation.

H 26: **Process management** will be positively associated with incremental process innovation.

H 27: **Process management** will be positively associated with administrative innovation.

3.10. Behavioural practices versus mechanistic practices

It is a common view that the impacts of behavioural QM practices can be achieved through mechanistic QM practices (Rahman, 2004). In this study, the proposed framework examines the relationship between behavioural and mechanistic practices. This is because the framework is based on the following narrative view: the appropriate application of behavioural

practices (e.g., management leadership) leads to the enhancement of mechanistic practices (e.g., processes management); subsequently, the impacts of the mechanistic practices result in innovation. Examining the relationship between behavioural and mechanistic practices is important because some empirical studies questioned the role of mechanistic practices in yielding improved performance (Powell, 1995; Samson and Terzioviski, 1999; Feng *et al.*, 2006).

A few researchers made an effort to explain the mixed findings on the link between behavioural and mechanistic practices. For instance, Flynn *et al.* (1995), in a study of 42 manufacturing plants in the United States, found that behavioural (infrastructure) practices can establish an environment to support the effective use of the mechanistic QM practices. The mechanistic (core) practices, on the other hand, are directly associated with quality performance by concentrating on the application of quality tools and continuous improvement. Similarly, Zu *et al.* (2008) developed a research model that includes infrastructure practices and core practices. Using 226 U.S. manufacturing plants, they concluded that behavioural practices are significantly related to mechanistic practices. Zu *et al.* (2008) argued that dividing QM practices into the behavioural and mechanistic practices is helpful to better identify the complex relationship among QM practices. However, the lack of empirical studies limits our understanding of how the positive effect of the behavioural practices on innovation is mediated by mechanistic practices. More studies are required to obtain further clarity on the link between behavioural and mechanistic practices (Rahman, 2004; Sousa and Voss, 2002). The following hypothesis deserves testing:

H 28: Behavioural QM practices will be positively associated with mechanistic QM practices.

3.11. Moderating variables

Proponents of QM advocated that the implementation of QM practices is universally beneficial in all types of organizations (Evans and Lindsay, 2008). While many organizations successfully implemented QM and improved their performance, a growing number of other organizations failed to accomplish benefits through QM (Douglas and Judge, 2001). Similarly, empirical studies questioned the QM proponents' arguments by positing that performance of QM can be achieved in an industry (e.g., manufacturing), but not in all types of organizations (e.g., Powell, 1995). To find an appropriate reason, researchers relied on the contingency theory – “an organization is above all an adaptive system which evolves by reacting to its environment” (Becheikh *et al.*, 2006, p. 656). For example, rigorous academic studies criticized the universal validity of QM practices by arguing that the performance of QM adoption is contingent on organizational contexts (Sila, 2007; Sousa and Voss, 2002). Similarly, other studies called for more research on the identification of potential moderator variables and their roles in a different context (Zaho *et al.*, 2004).

Unfortunately, researchers made little attempt to build a theory pertaining to the contextual variables. Furthermore, the inquiry into context dependence QM was developed at a slow pace (Nair, 2006). For instance, Sousa and Voss (2002), in a substantial literature review study, found only four studies that explored the contextual factors of QM practices. To further expand existing knowledge bases, this study examined three moderating factors – organizational structure, firm size, and the duration of QM adoption – that were regarded in the literature as important determinants of innovation and QM (Douglas and Judge, 2001; Salavou and Lioukas,

2003; Idris and Zairi, 2006). Consistent with the views of Nair (2006), it can be argued that examining the moderating factors helps to explain the inconsistent findings on the relationship between QM practices and innovation. This study focuses on the following moderating factors: firm size, the duration of QM adoption, structural control, structural exploration, and industry.

First, understanding the moderating effect of *firm size* is crucial because different features of organizations can influence the effectiveness of QM (Hannan and Freeman, 1984; Sila, 2007; Yeung *et al.*, 2006). Researchers reported different characteristics between small firms and large firms. Small firms, for example, are likely to be more customer focused, have good internal communication channels, have greater internal flexibility, have loose work processes and decentralized structures, are willing to take risks, and are more efficient (Bommer and Jalajas, 2004; Hendricks and Singhal, 2001; Teece *et al.*, 1997; Sila, 2007). In this aspect, small firms are more innovative than large firms, so small firms tend to concentrate on creating radical innovation (De Propriis, 2002; Broing and Herzog, 2008). In contrast, large firms have more employees and resources, more layers of management, a lack of internal flexibility, long-standing barriers among departments, formalized communication channels, and a bigger bureaucracy (Yeung *et al.*, 2006; Hendricks and Singhal, 2001; Bommer and Jalajas, 2004; Germain and Spears, 1999). Large firms are likely to have difficulty accomplishing major changes in products or services (Mohrman *et al.*, 1995). In this respect, large firms focus on current customers to generate returns today and on incremental innovation (Broring and Herzog, 2008; Bommer and Jalajas, 2004).

Existing studies support the moderating role of firm size on performance. For example, Hendricks and Singhal (2001), in an empirical study of 435 quality award winners, found that firm size is significantly related to the level of change in financial performance. According to

Hendricks and Singhal (2001), small firms do better than large firms because small firms already have some features that are similar to principles of QM, such as customer relations. Small firms are likely to establish an effective environment for organizational learning and assist better understanding of customer needs. These advantages of small firms lead to much profit. Similarly, Lopez-Mielgo *et al.* (2009), in an empirical study based on Spanish official survey data, concluded that there is a positive relationship between organizational standardization and quality control activities and firm size. Therefore, it can be expected that firm size moderates the relationship between QM practices and innovation.

Second, researchers consider *the duration of QM adoption* to be one of the most important variables (e.g., Idris and Zairi, 2006). On the basis of the QM principle of continuous improvement, proponents of QM argued that the impacts of QM can be achieved only if organizations are involved in QM efforts for a long period, such as at least three years (Schmidt and Finnigan, 1992). The QM literature indicates that QM entails excessive amounts of management time and resources necessary to produce performance (Powell., 1995; Sila, 2007; Yeung *et al.*, 2006). The long-term view on the implementation of QM is supported by previous studies. For instance, using data from 54 firms in the United States, Powell (1995) concluded that short-time adopters are less satisfied with QM programs than long-term adopters. Similarly, Ahire and Ravichandran (2001), in an empirical study of 407 plants in the automobile parts supplier industry, concluded that continuous learning on a long-term basis is positively related to quality performance. Reger *et al.* (1994) argued that the duration of QM implementation is significantly related to the degree to which organizations are involved in QM activities. Perdomo-Ortiz *et al.* (2006), in an empirical study of 102 machinery and instruments firms in

Spain, found that organizations with a long history of QM are more likely to establish innovation capability.

Third, it is important to examine structural control and structural exploration, because a supportive organizational structure is an essential condition to improve the impacts of QM adoption (Shea and Howell, 1998). The organizational structure can be split into two types: *structural control* and *structural exploration* (Douglas and Judge, 2001). There is substantial difference between the two types. In the structural control, organizations are likely to be larger and more centralized with tight processes and cultures (Hoffman and Hegarty, 1993; Benner and Tushman, 2003). The control-oriented organizations have a structured channel of communication and restrain the free flow of information (Cooper, 1998; Abrunhosa and Moura E Sá, 2008). In contrast, structural exploration is small and decentralized with loose processes (Benner and Tushman, 2003). Exploration organizations encourage employees to be involved in open and extensive interpersonal channels of communication (Abrunhosa and Moura E Sá, 2008). Empirical studies supported the importance of organizational structure. For instance, Douglas and Judge (2001), in a study of 229 general medical hospitals, found that organizational structure significantly moderates the relationship between QM practices and performance. Therefore, it is possible to expect that organizational structure can make an effect on the link between QM practices and innovation. Finally, it will be tested if there is a moderating effect of *industry* on the relationship between QM practices and innovation. Depending on the type of industry, the impacts of QM management might be different. Data will be split into two types of industries in terms of high technology industry or low technology industry. The classification rule is based on guidance proposed by Kaynak and Hartley (2005) who considered high technology industry

encompassing seven industries, such as chemicals and allied products and transportation equipment. The above discussion leads to the following hypotheses:

H 29: **Firm size** will moderate the relationship between QM and innovation.

H 30: **The duration of QM adoption** will moderate the relationship between QM and innovation.

H 31: **Structural control** will moderate the relationship between QM and innovation.

H 32: **Structural exploration** will moderate the relationship between QM and innovation.

H 33: **Type of Industry** will moderate the relationship between QM and innovation.

4. Methods

This section presents the sample, data collection procedures, and measures used in this study.

4.1. Sample and data collection

A *target sample* of 2,100 ISO 9001 certified manufacturing or service companies, listed in the Scottsinfo.com database, was selected. A stratified sampling technique was used to obtain data from different sizes of companies: large-sized, medium-sized, and small-sized companies. Both manufacturing and service companies were considered for the following three reasons. First, QM was widely adopted and practised in the industries for the last few decades. Therefore, QM studies should be conducted for a broad range of industries. Second, innovation is considered to be an important option to build competitive advantage in any organization (Lloréns Montes *et al.*, 2005; Veryzer, 1998; Di Benedetto *et al.*, 2008). Third, the cross-sectional approach will increase the generalizability of findings beyond the bounds of a single industry. The argument that both manufacturing and services companies should be included is consistent with the sampling methods of previous empirical studies conducted in the manufacturing and service industries (e.g., Hoang *et al.*, 2006; Prajogo and Sohal, 2004; Santos-Vijande and Álvarez-González, 2007; Martinez-Costa and Martinez-Lorente, 2008).

The *unit of analysis* is the organizational level as this study seeks to find out whether QM practices lead to organizational innovation. Earlier studies were conducted at the plant level (e.g., Flynn *et al.*, 1995; Anderson *et al.*, 1995; Rungtusanatham *et al.*, 1998; Ahire and Ravichandran, 2001; Zu *et al.*, 2008). However, an organizational level study will add depth to the QM literature since there is a relative lack of studies investigating linkages of QM practices (e.g., Kaynak, 2003; Sila and Ebrahimpour, 2005). Further, in designing a questionnaire, two guidelines suggested by Frohlich (2002) were considered as follows: increasing respondents' perceived relevance and reducing respondents' expected effort. ISO 9001 certified companies were selected to improve respondents' perceived relevance. This is because many companies invested in projects that provide training programs or maintain the ISO 9001 certification every three years. Further, to reduce respondents' perceived effort, a brief questionnaire was designed. The questionnaire contained only 65 questions. This attempt was aimed at reducing respondents' expected time and retaining respondents' attention while answering a questionnaire. With respect to the questions' reliability and validity, most questions were adapted or borrowed from the literature, so they were expected to clearly and appropriately operationalize constructs. However, to ensure the appropriateness of the constructs, eleven researchers reviewed the questionnaire and suggested improvements in terms of ambiguity and readability. The final version of the questionnaire was prepared through this revision procedure.

A *questionnaire* and a cover letter were mailed to 2,100 respondents. A total of 242 questionnaires were completed and returned. 23 questionnaires were returned undelivered because the respondents moved or were unknown. The 19 incomplete responses were excluded because of a large number of missing values for questions pertaining to innovation. One of the main reasons was that the questions are not applicable in companies. The analysis is based on a

sample of 223 ISO 9001 certified manufacturing or service companies, and the response rate is 10.6 per cent (See Table 4).

The *respondents* were company executives, middle-level managers, and professional staff. It was assumed that they were sufficiently well informed of the extent and impacts of QM practices in their companies to provide correct information. Similarly, previous studies reported that the commitment and knowledge of the executives and managers is extremely crucial when implementing QM (e.g., Burke, 1999). The sample consisted of 22 service companies (9.9 %) and 201 manufacturing companies (90.1%). The manufacturing companies represented the following industries: 10 primary metal manufacturing (4.5%, NAICS code 331); 15 machinery manufacturing (6.7%, NAICS code 333); 15 transportation equipment manufacturing (6.7%, NAICS code 336); 13 chemical manufacturing (5.8%, NAICS code 325); 29 fabricated metal product manufacturing (13.0%, NAICS code 332); 18 computer and electronic product manufacturing (8.1%, NAICS code 334); 11 electrical equipment, appliance, and component manufacturing (4.9%, NAICS code 335); and other industries (40%), such as construction and food packaging. In this study, seven industries (NAICS code 331, 333, 336, 325, 332, 334, and 335) were analyzed separately because earlier studies viewed them to be high technology organizations that tend to significantly create innovation (Kaynak and Hartley, 2005). To examine the interaction effects of the industry, this study examined the difference between high technology organizations and low technology organizations. Further, with respect to the duration of ISO 9001 adoption, about 71% (158) of the respondents stated that ISO 9001 system was implemented in their organizations for more than three years, while 28% (62) of the respondents stated that their organizations have been following the system for less than three years. Table 4 shows descriptive summary of respondents.

Table 4. Descriptive summary of respondents

	Number of respondents
Respondents	Mailed questionnaire: 2,100 Returned questionnaire: 23 (1.1%) Completed questionnaire: 242 (11.5%) Incomplete questionnaires: 19 (0.9%) Usable responses: 223 (Response rate, 10.6%)
Industry	Service: 22 (9.9%) Primary metal manufacturing: 10 (4.5%) Machinery manufacturing: 15 (6.7%) Transportation equipment manufacturing: 15 (6.7%) Chemical manufacturing: 13 (5.8%) Fabricated metal product manufacturing: 29 (13.0%) Computer and electronic product manufacturing: 18 (8.1%) Electrical equipment, appliance, and component manufacturing: 11 (4.9%) Other industries: 90 (40%)
Size of organizations	Less than 50: 74 (33.2%) Between 50 – 500: 105 (47.1%) Over 500: 44 (19.7%)
Duration of ISO 9001 adoption	Less than 3 years: 62 (27.8%) More than 3 years: 158 (70.9%) Not applicable: 3 (1.3%)

A *screening procedure* was performed on the data. Data were recorded into a Microsoft Excel file. To ensure the accuracy of data entry, the coded data were examined two times. Next, it was required to employ a technique dealing with missing observations. Although there is a debate on the use of an appropriate technique, it is a common view that the mean substitution for missing item is the most common and basic method (Chhabra *et al.*, 2002; Kline, 2005; Roth and Switzer, 1995). Missing values (62) were replaced by the mean value of the variable.

Further, *normality* of data was examined by testing for skewness, kurtosis, and outliers. It is important to examine normality when using structural equation modeling (SEM). One of the assumptions in SEM is that the data is normally distributed. A distribution is not normal if data shows skewness and kurtosis (Kline, 2005). Skewness refers to the asymmetry of a distribution, while kurtosis is a measure of the peakedness of a distribution (Mandelbrot, 1967). The literature shows that the distribution is normal when skewness ranges from -2 to +2, and kurtosis ranges from -7.0 to +7.0 (Curran *et al.*, 1996). Table 5 indicates that all of the indicator values are normally distributed.

Table 5. Descriptive statistics of indicators

Item	Minimum	Maximum	Mean	Std. Deviation	Skewness Statistic	Kurtosis Statistic
<i>Items related to QM practices</i>						
MAL1	1	7	6.081	1.220	-0.672	-0.473
MAL2	1	7	5.973	1.178	-0.509	-0.540
MAL3	1	7	6.108	1.130	-0.653	-0.527
MAL4	1	7	5.507	1.342	-0.344	-0.611
MAL5	1	7	6.027	1.280	-0.668	-0.528
MAL6	1	7	5.942	1.349	-0.620	-0.566
TRA1	1	7	5.126	1.256	-0.098	-0.295
TRA2	1	7	5.027	1.135	-0.078	-0.203
TRA3	1	7	5.108	1.188	-0.099	-0.283
EMR1	1	7	5.072	1.088	-0.069	-0.203
EMR2	1	7	4.821	1.179	-0.041	-0.253
EMR3	1	7	5.197	1.138	-0.108	-0.284
EMR4	1	7	5.152	1.202	-0.118	-0.343
SQM1	1	7	5.184	1.348	-0.163	-0.525
SQM2	1	7	4.749	1.382	-0.083	-0.267
SQM3	1	7	4.462	1.321	-0.058	-0.140

Item	Minimum	Maximum	Mean	Std. Deviation	Skewness Statistic	Kurtosis Statistic
SQM4	1	7	5.040	1.303	-0.112	-0.425
SQM5	1	7	4.691	1.362	-0.066	-0.277
SQM6	1	7	4.525	1.273	-0.048	-0.128
CUR1	1	7	5.619	1.231	-0.297	-0.548
CUR2	1	7	5.179	1.121	-0.101	-0.273
CUR3	1	7	5.498	1.158	-0.209	-0.392
CUR4	1	7	5.274	1.186	-0.141	-0.368
QDR1	1	7	5.157	1.276	-0.140	-0.443
QDR2	1	7	4.973	1.170	-0.078	-0.223
QDR3	1	7	5.049	1.171	-0.104	-0.184
QDR4	1	7	5.148	1.312	-0.156	-0.333
PSD1	1	7	5.247	1.247	-0.149	-0.434
PSD2	1	7	4.919	1.152	-0.065	-0.214
PSD3	1	7	5.085	1.130	-0.123	-0.169
PSD4	1	7	5.318	1.238	-0.161	-0.437
PRM1	1	7	4.498	1.150	-0.040	-0.050
PRM2	1	7	4.516	1.417	0.064	-0.535
PRM3	1	7	4.673	1.188	-0.033	-0.211
PRM4	1	7	4.897	1.267	-0.089	-0.276
<i>Items related to innovation</i>						
RPDI1	1	7	3.870	1.792	0.032	-0.549
RPDI2	1	7	4.031	1.824	-0.014	-0.650
RPDI3	1	7	3.803	1.538	0.022	-0.285
RPDI4	1	7	3.753	1.767	0.078	-0.584
RPDI5	1	7	3.700	1.849	0.088	-0.680
IPDI1	1	7	4.785	1.297	-0.085	-0.152
IPDI2	1	7	4.767	1.355	-0.088	-0.213
IPDI3	1	7	4.619	1.444	-0.068	-0.328
IPDI4	1	7	4.628	1.372	-0.057	-0.293
IPDI5	1	7	4.673	1.496	-0.090	-0.340
RPCI1	1	7	4.543	1.503	-0.076	-0.288
RPCI2	1	7	4.646	1.472	-0.090	-0.257
RPCI3	1	7	4.516	1.458	-0.070	-0.255
IPCI1	1	7	4.861	1.310	-0.095	-0.288
IPCI2	1	7	4.789	1.240	-0.049	-0.286

Item	Minimum	Maximum	Mean	Std. Deviation	Skewness Statistic	Kurtosis Statistic
IPCI3	1	7	4.744	1.316	-0.049	-0.393
ADMI1	1	7	4.673	1.403	-0.080	-0.247
ADMI2	1	7	4.220	1.295	-0.023	-0.115
ADMI3	1	7	4.475	1.442	-0.052	-0.256
ADMI4	1	7	3.511	1.879	0.138	-0.693

Labels: MAL, Management leadership; TRA, Training; EMR, Employee relations; SQM, Supplier quality management; CUR, Customer relations; QDR, Quality data & reporting; PSD, Product/service design; PRM, Process management; RPDI, Radical product innovation; IPDI, Incremental product innovation; RPCI, Radical process innovation; IPCI, Incremental process innovation; ADMI, Administrative innovation.

Outliers refer to data points that split off or differ from rest of the data (Stevens, 1996, p. 12). The potential influence of outliers was assessed using the Mahalanobis distance statistics. The Mahalanobis distance represents the distance in standard deviation units between a set of scores for an individual case and the sample means for all variables (Kline, 2005, p. 51). It is assumed that the Mahalanobis distance is distributed as chi-square statistics (Kline, 2005). A chi-square (χ^2) test was performed to examine the Mahalanobis distance. There is no outlier if the Mahalanobis distance is lower than a critical value (26.13). Table 6 indicates that the Mahalanobis distance ranged from 1.221 to 25.880. It is concluded that there is no evidence of outliers in the analysis.

Table 6. Result of test for analyzing outliers

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	2.810846	5.547184	4.469387	.5578688	223
Std. Predicted Value	-2.973	1.932	.000	1.000	223

Standard Error of Predicted Value	.067	.232	.129	.034	223
Adjusted Predicted Value	2.836820	5.531468	4.470169	.5583648	223
Residual	-2.5366664	1.3519892	.0000000	.6535276	223
Std. Residual	-3.811	2.031	.000	.982	223
Stud. Residual	-3.844	2.073	-.001	1.000	223
Deleted Residual	-2.5807352	1.4088610	-.0007814	.6786381	223
Stud. Deleted Residual	-3.975	2.090	-.002	1.006	223
Mahal. Distance	1.221	25.880	7.964	4.907	223
Cook's Distance	.000	.041	.004	.006	223
Centered Leverage Value	.006	.117	.036	.022	223

Critical value of eight independent variables ($p < 0.001$): 26.13

Eight independent variables: Management leadership; Training; Employee relations; Supplier quality management; Customer relations; Quality data & reporting; Product/service design; Process management

Dependent variable: Innovation

To examine possible bias in a self-report survey data, a non-response bias test and Harmon's one-factor test were conducted. ***Non-response bias*** was assessed by performing a *t*-test on the scores of early and late respondents. A basic assumption is that the late respondents stand for opinions of non-respondents (Armstrong and Overton, 1977). Respondents were divided into two groups: 171 responses (76.7%) that were received in December 2009 and 52 responses (23.3%) that were received in January and February 2010. The purpose of the analysis was to identify any difference between the two groups in eight independent variables (e.g., management leadership and customer relations) and five dependent variables (e.g., radical process innovation and administrative innovation). The *t*-test showed no significant difference in the two groups, indicating that the data is free from non-response bias. Table 7 shows results of student's *t*-test.

Table 7. Result of student's t-test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
MAL	Equal variances assumed	2.298	.131	-.128	221	.898	-.0204303	.1594435	-.3346547	.2937940
	Equal variances not assumed			-.154	120.472	.878	-.0204303	.1322646	-.2822946	.2414339
TRA	Equal variances assumed	1.172	.280	1.055	221	.293	.1715774	.1626576	-.1489810	.4921359
	Equal variances not assumed			1.120	93.115	.266	.1715774	.1532348	-.1327116	.4758665
EMR	Equal variances assumed	.509	.476	1.606	221	.110	.24196	.15069	-.05501	.53893
	Equal variances not assumed			1.677	90.504	.097	.24196	.14431	-.04472	.52864
SQM	Equal variances assumed	.113	.737	1.216	221	.225	.1789436	.1471231	-.1110002	.4688875
	Equal variances not assumed			1.175	80.232	.243	.1789436	.1522363	-.1240029	.4818901
CUR	Equal variances assumed	.269	.604	1.142	221	.255	.17940	.15715	-.13031	.48911
	Equal variances not assumed			1.178	88.754	.242	.17940	.15227	-.12316	.48196
QDR	Equal variances assumed	3.049	.082	.446	221	.656	.07538	.16893	-.25754	.40829
	Equal variances not assumed			.482	96.198	.631	.07538	.15628	-.23484	.38559
PSD	Equal variances assumed	.015	.904	1.170	221	.243	.19194	.16402	-.13130	.51519
	Equal variances not assumed			1.160	83.302	.249	.19194	.16543	-.13707	.52095
PRM	Equal variances assumed	.043	.836	.601	221	.548	.08974	.14930	-.20450	.38399
	Equal variances not assumed			.602	84.533	.549	.08974	.14914	-.20682	.38630
RPDI	Equal variances assumed	3.596	.059	-.179	221	.858	-.0443320	.2473387	-.5317762	.4431122

	Equal variances not assumed					.843	-.0443320	.2236871	-.4880993	.3994353
IPDI	Equal variances assumed	1.202	.274	-.804	221	.422	-.1580747	.1966631	-.5456498	.2295004
	Equal variances not assumed					.376	-.1580747	.1779046	-.5110173	.1948680
RPCI	Equal variances assumed	.006	.936	-.973	221	.331	-.2038911	.2094579	-.6166816	.2088993
	Equal variances not assumed					.342	-.2038911	.2134614	-.6285323	.2207501
IPCI	Equal variances assumed	1.881	.172	-.971	221	.332	-.1795622	.1848401	-.5438369	.1847126
	Equal variances not assumed					.378	-.1795622	.2024158	-.5828490	.2237247
ADMI	Equal variances assumed	.042	.838	-1.092	221	.276	-.2089519	.1913126	-.5859823	.1680786
	Equal variances not assumed					.283	-.2089519	.1931835	-.5931757	.1752720

Labels: MAL, Management leadership; TRA, Training; EMR, Employee relations; SQM, Supplier quality management; CUR, Customer relations; QDR, Quality data & reporting; PSD, Product/service design; PRM, Process management; RPDI, Radical product innovation; IPDI, Incremental product innovation; RPCI, Radical process innovation; IPCI, Incremental process innovation; ADMI, Administrative innovation.

The *common method variance* was tested using Harmon's one-factor test (Schriesheim, 1979). This is because the questionnaire in this study included most subjective measures completed by a single source (Scott and Bruce, 1994). Common method variance is identified as a potential error in which a correlation between two measures may be due to the fact that both come from the same source, rather than a substantive relationship between them (Rothbard, 2001, p. 679). Confirmatory factor analysis (CFA) using linear structural relations (LISREL) was conducted for Harmon's one-factor test (Boyer and Hult, 2005, b). A single latent factor would account for most of the covariance in variables if the data has a problem with the common method variance (Podsakoff and Organ, 1986; Barringer and Bluedorn, 1999). In other words,

common method variance appears in a structural model that poorly fits the data (Kim, 2009). A single factor model using the construct of management leadership was analyzed. The analysis result indicated that the fit of the model is significantly worse ($\chi^2 = 5588.86$; degree of freedom = 1274; the ratio of χ^2 to degree of freedom = 4.39). Thus, the data is free from common method bias and non-response bias.

4.2. Measures

It is important to design measurement items that can capture the nature of variables. In this study, a total of 65 measures were adapted or borrowed from the literature. The measures are divided into three categories: independent variables (QM practices), dependent variables (innovation), and moderating variables (firm size, industry, structural control, structural exploration, and the duration of QM adoption). Most measures used a seven-point Likert-type scale ranging from strongly disagree to strongly agree. A similar attempt using the seven-point Likert type was also used in prior empirical studies (e.g., Ahire and Ravichandran, 2001; Zu *et al.*, 2008).

Measurement items for QM practices were based on instruments originally developed by Saraph *et al.* (1989). Although numerous researchers used and customized the original survey instrument, this study adapted 31 measurement items tested by Kaynak (2003). In Kaynak's (2003) study, the measurement items were examined in a relatively large sample size of 214 manufacturing and service industries. However, Kaynak (2003) missed a construct that is important when understanding a customer perspective. This study added a construct, which is

entitled “customer relations.” This is because establishing a good relationship with customers is one of the representative goals of QM. Measurement items for customer relations were borrowed from the studies of Flynn *et al.* (1995) and Zu *et al.* (2008). For example, the construct “customer relations” was measured by indicators evaluating the extent to which a company is in close contact with its customers, employees know their customers, customers give feedback on quality and delivery performance, and customers visit the office or workplace.

Measurement items for innovation were adapted from the innovation literature, such as Herrmann, *et al.* (2007), Chandy and Tellis (1998), Valle and Vázquez-Bustelo (2009), Jansen *et al.* (2006), and Martinez-Costa and Martinez-Lorente (2008). In particular, this study evaluates innovation with multiple measurement items. This attempt is consistent with that of prior studies (e.g., Wan *et al.*, 2005), that argue that an empirical study on innovation should not rely on only a single or a few innovation related items, such as R&D expenditures and patent counts. In this study, for example, the construct of radical product innovation was operationalized by five items reflecting the extent to which new products differ substantially from other existing products, a company introduces radical product innovation into the market more frequently than competitors, a percentage of radical product innovations in the product range is significantly higher compared to the competition, the percentage of total sales from radical product innovation is up substantially, and a company is well known by customers for radical product innovations.

Moderating constructs were added to examine whether the constructs influence the relationship between QM practices and innovation. First of all, structural exploration and structural control were adapted from a study conducted by Douglas and Judge (2001). Following a guideline suggested by Douglas and Judge (2001), this study split organizational structure into two sub-areas: structural exploration and structural control. The construct “structural

exploration” was operationalized by items tapping the extent to which a company allows the freedom to change previous practices to fit a changing environment and encourages the flow of operating and financial information. On the other hand, the construct “structural control” was operationalized using three items reflecting the extent to which a company highlights the control of systems, procedures, and job descriptions. Another moderating construct was firm size representing a small-sized company (fewer than 50), a medium-sized company (between 50 and 500), and a large-sized company (more than 500). This classification is based on studies which analyzed Canadian businesses sectors (e.g., Debus, 2005). The classification is appropriate for this study since data were collected in Canadian manufacturing and service companies. Another moderating construct, the duration of QM adoption, was operationalized by the following indicators: less than 3 years; more than 3 years; not applicable. The measures for the constructs were adapted from earlier studies, such as Terziovski *et al.* (1997) and Powell (1995). Individual measurement items and definitions are given in Appendix B and C.

5. Analysis and results

This section describes the analysis results of the measurement models and hypothesis testing.

Structural equation modeling (SEM) technique using LISREL was employed to analyze the measurement models and the structural models in this study. SEM is a technique to specify, estimate, and evaluate models of linear relationships among a set of observed variables in terms of a generally smaller number of unobserved variables (Shah and Goldstein, 2006, p. 149). Both measurement models and structural models can be examined using SEM (Gefen *et al.*, 2000). A SEM model comprises of latent variables and observed variables. Each latent variable consists of a different number of observed variables (Kline 2005). SEM enables researchers not only to identify estimates of the model parameters and standard errors, but also to explore multiple relationships simultaneously (Kerlinger and Lee, 2000).

5.1. Measurement analysis

It is essential to test hypotheses without any measurement influences related to reliability, unidimensionality, and validity (Shah and Goldstein, 2006). A three-stage approach was employed to ensure that measurement items are reliable, unidimensional, and valid.

Reliability Assessment

In the first stage, **reliability** was assessed to identify the degree to which measures are free from random measurement error (Kline, 2005). Reliability refers to the instrument's ability to offer consistent results over time (Gatewood and Field, 1990). CFA using LISREL was performed to explore reliability. Based on the results of CFA, two different methods were used (Carr and Pearson, 1999; Boyer and Hult, 2005 b) analyzing the squared multiple correlation (R^2) and examining the composite reliability and the average variance extracted.

First, reliability was examined by analyzing the squared multiple correlation (R^2) of individual items. The R^2 -values in a measurement model were computed as one minus the ratio of the disturbance variance over the total variance (Kline, 2005, p. 252). Within the CFA setting, the R^2 value of an individual item should be greater than 0.30 (Carr and Pearson, 1999). However, it was found that the R^2 values of four items were below 0.30: SQM2 (0.14), SQM3 (0.07), PRM2 (0.15), and ADMI4 (0.18). Thus, based on the analysis results, four items were dropped at this stage.

Further, the composite reliability and the average variance extracted were calculated using completely standardized solutions in the CFA results. (See formulas in Table 8) These two indices are widely used to test for reliability in the literature (e.g., Hult *et al.*, 2004). According to a rule of thumb, the composite reliability of over 0.7 or the average variance extracted of over 0.5 indicates acceptable reliability levels (Fornell and Larcker, 1981; Kim, 2009). As Table 10 shows, the composite reliabilities ranged from 0.795 to 0.935, while the average variance

extracted ranged from 0.564 to 0.742. The results reveal that all measures have a reasonable level of reliability.

Table 8. Formulas to calculate composite reliability and average variance extracted

	Formula	
Composite reliability (CR)	$CR_{\eta} = \frac{(\sum \lambda_{\gamma_i})^2}{(\sum \lambda_{\gamma_i})^2 + (\sum \varepsilon_i)}$	<p>CRη = composite reliability for scale η</p> <p>λ_{γ_i} = standardized loading for scale item γ_i</p> <p>ε_i = measurement error for scale item γ_i</p>
Average variance extracted (AVE)	$V_{\eta} = \frac{(\sum \lambda_{\gamma_i}^2)}{(\sum \lambda_{\gamma_i}^2) + (\sum \varepsilon_i)}$	<p>Vη = average variance extracted for scale η</p> <p>λ_{γ_i} = standardized loading for scale item γ_i</p> <p>ε_i = measurement error for scale item γ_i</p>

Source: Boyer and Hult (2005, b, p. 653)

Unidimensionality Assessment

In the second stage, to test for *unidimensionality*, exploratory factor analysis (EFA) and CFA were performed. Unidimensionality refers to the extent to which the measures in a scale reflect one underlying construct (Venkatraman and Grant, 1986). To satisfy the requirement for unidimensionality, an indicator should rely on just one factor, while error terms are independent (Anderson and Gerbing, 1988). SPSS was employed for conducting EFA using principle component analysis with a varimax rotation. Items of QM practices and those of innovation were

separately analyzed. Unidimensionality could be established if an eigenvalue of each item is greater than 0.40 (Bhuan *et al.*, 2005). The eigenvalues indicate that measurement items for QM were loaded onto eight factors and that measurement items for innovation were loaded onto five factors. Eigenvalues of all items ranged from 0.550 to 0.904 (See Appendixes D and E).

CFA was also conducted to test for unidimensionality. The model fit was assessed by reviewing a set of indices: Comparative Fit Index (CFI), Root Mean Square Error of Approximation (RMSEA), the ratio of χ^2 to degree of freedom (χ^2/df), Normed Fit Index (NFI), and Non-Normed Fit Index (NNFI). The literature suggested that the use of a set of indices is superior to the application of a single index because each index has strengths and weaknesses (Kline, 2005; Hu and Bentler, 1999). For example, RMSEA is likely to overreject models at a small sample size (Hu and Bentler, 1999), while CFI is a relatively stable fit index (Gerbing and Anderson, 1992). The indices have different rules to determine excellent fit as follows: CFI, NFI, and NNFI > 0.9 (Bentler and Bonett, 1980; Byrne, 1998); RMSEA < 0.08 (Browne and Cudeck, 1993); χ^2/df < 3.0 (Carmines and McIver, 1981; Bollen, 1989).

CFA was conducted to separately examine measurement models of each construct, such as management leadership, training, and employee relations. The goodness of fit statistics showed a good fit of all measurement models to the data (See Appendixes F and G). Moreover, after testing the measurement models of each construct, CFA was again performed to assess two measurement models: one for QM practices and the other for innovation. This attempt at assessing the two measurement models is consistent with an assessment methodology suggested by Kaynak (2003). In terms of additional information, the results of CFA show an acceptable fit for both measurement models. In the measurement model for QM practices, the indices are as follows: CFI = 0.99; RMSEA = 0.039; χ^2/df = 630/456 = 1.38; NFI = 0.96; and NNFI = 0.99.

Similarly, the measurement model for innovation shows good fit statistics: CFI = 0.97; RMSEA = 0.077; $\chi^2/\text{df} = 316/147 = 2.15$; NFI = 0.94; and NNFI = 0.96. Thus, it is concluded that all constructs are unidimensional. Table 9, Figure 2, and Figure 3 show analysis results of the measurement models.

Table 9. Analysis results of the measurement models

Goodness of fit statistics	Measurement model for QM practices	Measurement model for innovation	Suggested values for fitting date (Source)
Comparative Fit Index (CFI)	0.99	0.97	> 0.9 (Bentler and Bonett, 1980; Byrne, 1998)
Root Mean Square Error of Approximation (RMSEA)	0.039	0.077	< 0.08 (Browne and Cudeck, 1993)
the ratio of χ^2 to degree of freedom (χ^2/df)	630/456 = 1.38	316/147 = 2.15	< 3.0 (Carmines and McIver, 1981; Bollen, 1989).
Normed Fit Index (NFI)	0.96	0.94	> 0.9 (Bentler and Bonett, 1980; Byrne, 1998)
Non-Normed Fit Index (NNFI)	0.99	0.96	> 0.9 (Bentler and Bonett, 1980; Byrne, 1998)

Figure 2. A measurement model for QM practices

Figure 3. A measurement model for innovation

Validity Assessment

In the third stage, **validity** was assessed in terms of convergent validity and discriminant validity. **Convergent validity** is identified as the extent to which multiple attempts to measure the same concept are in agreement (Bagozzi and Phillips, 1982). Convergent validity can be evaluated by examining the *t*-value from CFA (Chen *et al.*, 2004; Sila and Ebrahimpour, 2005). Each item's coefficients on its underlying construct were observed (Anderson and Gerbing, 1988). A measure should have convergent validity if the value of its coefficient is greater than

twice its standard error. In other words, the *t*-values should be greater than two to achieve strong convergent validity, where the *t*-values are calculated by dividing the value of the coefficient by the standard error. The *t*-values in this study ranged from 9.811 to 17.970. All measures have strong evidence of convergent validity.

Table 10. Factor loading, standardized loading, standard errors, and t-values

Factors and items	Factor loading	Standardized loading	Standard error	<i>t</i> -value	R ²	Composite reliability	Average variance extracted (AVE)
MAL						0.893	0.584
MAL1	1.000	0.841	-	-	0.708		
MAL2	0.855	0.745	0.068	12.560	0.556		
MAL3	0.896	0.814	0.063	14.247	0.663		
MAL4	0.937	0.717	0.079	11.899	0.514		
MAL5	0.960	0.770	0.073	13.150	0.593		
MAL6	0.901	0.686	0.080	11.219	0.470		
TRA						0.866	0.685
TRA1	1.000	0.744	-	-	0.554		
TRA2	1.143	0.867	0.090	12.709	0.751		
TRA3	1.195	0.865	0.094	12.692	0.749		
EMR						0.850	0.586
EMR1	1.000	0.730	-	-	0.533		
EMR2	1.052	0.709	0.104	10.079	0.502		
EMR3	1.156	0.808	0.101	11.479	0.652		
EMR4	1.227	0.811	0.106	11.527	0.658		
SQM						0.859	0.607
SQM1	1.000	0.817	-	-	0.668		
SQM4	1.019	0.862	0.073	14.042	0.743		
SQM5	0.967	0.782	0.077	12.615	0.612		
SQM6	0.737	0.638	0.075	9.811	0.407		
CUR						0.868	0.625
CUR1	1.000	0.886	-	-	0.785		
CUR2	0.759	0.739	0.060	12.675	0.546		
CUR3	0.884	0.833	0.059	14.980	0.694		
CUR4	0.748	0.688	0.065	11.463	0.473		
QDR						0.886	0.661
QDR1	1.000	0.794	-	-	0.631		
QDR2	0.909	0.787	0.071	12.766	0.620		

Factors and items	Factor loading	Standardized loading	Standard error	t-value	R ²	Composite reliability	Average variance extracted (AVE)
QDR3	0.934	0.808	0.071	13.209	0.654		
QDR4	1.115	0.861	0.078	14.321	0.742		
PSD						0.895	0.680
PSD1	1.000	0.835	-	-	0.697		
PSD2	0.912	0.824	0.063	14.520	0.680		
PSD3	0.928	0.856	0.061	15.332	0.732		
PSD4	0.925	0.788	0.069	13.354	0.606		
PRM						0.795	0.564
PRM1	1.000	0.785	-	-	0.617		
PRM3	0.958	0.729	0.092	10.451	0.532		
PRM4	1.034	0.737	0.098	10.563	0.543		
RPDI						0.934	0.739
RPDI1	1.000	0.766	-	-	0.587		
RPDI2	1.205	0.907	0.081	14.908	0.823		
RPDI3	0.931	0.831	0.070	13.380	0.691		
RPDI4	1.170	0.909	0.078	14.947	0.826		
RPDI5	1.181	0.877	0.083	14.303	0.769		
IPDI						0.935	0.742
IPDI1	1.000	0.826	-	-	0.681		
IPDI2	1.178	0.930	0.066	17.970	0.866		
IPDI3	1.208	0.896	0.071	16.931	0.804		
IPDI4	1.058	0.826	0.071	14.858	0.682		
IPDI5	1.149	0.822	0.078	14.759	0.676		
RPCI						0.878	0.705
RPCI1	1.000	0.849	-	-	0.721		
RPCI2	1.012	0.877	0.069	14.705	0.769		
RPCI3	0.904	0.791	0.068	13.324	0.626		
IPCI						0.891	0.733
IPCI1	1.000	0.892	-	-	0.796		
IPCI2	0.906	0.854	0.058	15.753	0.729		
IPCI3	0.924	0.820	0.062	14.984	0.673		
ADMI						0.848	0.651
ADMI1	1.000	0.814	-	-	0.663		
ADMI2	0.882	0.778	0.075	11.703	0.605		
ADMI3	1.044	0.827	0.085	12.222	0.685		

All t-values are significant at P < 0.01 level.

Four items (SQM2, SQM3, PRM2, and ADMI4) were dropped at the first analysis stage.

Discriminant validity refers to the extent to which a given construct is different from other constructs (John and Reve, 1982, p. 520). To test for discriminant validity, three approaches were used. The first approach was to perform a chi-square difference test on all pairs

of constructs via CFA (Bagozzi and Phillips, 1982). For the test, it was necessary to develop two models in each pair of constructs: a constrained model and an unconstrained model. In the constrained model, a correlation parameter of a pair of constructs was constrained at 1. On the other hand, in the unconstrained model, a correlation parameter was set to be free. A χ^2 difference value was calculated by subtracting a χ^2 of the unconstrained model from a χ^2 of the constrained model. To verify discriminant validity, the χ^2 difference value should be greater than 3.84 (Liang and Chen, 2009; Kim, 2009). CFA was run on 38 pairs of constructs twice. The χ^2 difference values ranged from 4.135 to 41.859 (See Table 11). This result indicates that constructs exhibit strong discriminant validity.

Table 11. Discriminant validity assessment using a χ^2 difference

Pair of constructs	Constrained model (Corr.=1)		Unconstrained model (Corr. = free)		Difference	
	χ^2	df	χ^2	df	$\Delta\chi^2_{(df=1)}$	Sig.
<i>QM Practices</i>						
MAL – TRA	67.683	27	45.341	26	22.342	p < 0.05
MAL – EMR	87.801	35	58.606	34	29.195	p < 0.05
MAL – SQM	99.679	35	75.436	34	24.243	p < 0.05
MAL – CUR	70.173	35	48.613	34	21.560	p < 0.05
MAL – QDR	77.075	35	47.663	34	29.412	p < 0.05
MAL – PSD	63.385	35	49.009	34	14.376	p < 0.05
MAL – PRM	83.046	27	41.187	26	41.859	p < 0.05
TRA – EMR	46.293	14	20.427	13	25.866	p < 0.05
TRA – SQM	59.855	14	36.888	13	22.967	p < 0.05
TRA – CUR	46.217	14	22.172	13	24.045	p < 0.05
TRA – QDR	33.214	14	22.559	13	10.655	p < 0.05
TRA – PSD	37.930	14	22.331	13	15.599	p < 0.05
TRA – PRM	31.654	9	8.946	8	22.708	p < 0.05
EMR – SQM	67.866	20	45.723	19	22.143	p < 0.05
EMR – CUR	54.381	20	23.591	19	30.790	p < 0.05
EMR – QDR	48.526	20	34.570	19	13.956	p < 0.05
EMR – PSD	51.119	20	38.967	19	12.152	p < 0.05

Pair of constructs	Constrained model (Corr.=1)		Unconstrained model (Corr. = free)		Difference	
	χ^2	df	χ^2	df	$\Delta\chi^2_{(df=1)}$	Sig.
EMR – PRM	44.984	14	20.591	13	24.393	p < 0.05
SQM – CUR	94.443	20	76.555	19	17.888	p < 0.05
SQM – QDR	51.702	20	42.111	19	9.591	p < 0.05
SQM – PSD	60.002	20	52.807	19	7.195	p < 0.05
SQM – PRM	61.360	14	47.662	13	13.698	p < 0.05
CUR – QDR	49.542	20	37.044	19	12.498	p < 0.05
CUR – PSD	46.457	20	28.372	19	18.085	p < 0.05
CUR – PRM	54.922	14	21.782	13	33.140	p < 0.05
QDR – PSD	41.534	20	37.305	19	4.229	p < 0.05
QDR – PRM	35.776	14	27.620	13	8.156	p < 0.05
PSD – PRM	30.787	14	23.152	13	7.635	p < 0.05
<i>Innovation</i>						
RPDI – IPDI	134.251	27	130.116	26	4.135	p < 0.05
RPDI – RPCI	46.226	20	38.991	19	7.235	p < 0.05
RPDI – IPCI	66.792	20	42.450	19	24.342	p < 0.05
RPDI – ADMI	49.271	20	37.857	19	11.414	p < 0.05
IPDI – RPCI	60.544	14	46.002	13	14.542	p < 0.05
IPDI – IPCI	53.839	14	42.012	13	11.827	p < 0.05
IPDI – ADMI	67.316	14	51.658	13	15.658	p < 0.05
RPCI – IPCI	44.412	9	34.669	8	9.743	p < 0.05
RPCI – ADMI	20.722	9	15.068	8	5.654	p < 0.05
IPCI – ADMI	23.865	9	8.170	8	15.695	p < 0.05

The critical value: $\Delta\chi^2_{(df=1)} > 3.84$ (Boyer and Hult, 2005, a)

Alternatively, the second approach for testing discriminant validity was to compare the Cronbach's α of a construct and its correlations with other constructs (Kaynak, 2003). According to a rule of thumb, discriminant validity can be achieved if the Cronbach's α is greater than the correlations (Sila and Ebrahimpour, 2005). It was found that Cronbach's α values are greater than correlations (See Table 12). The third approach, proposed by Fornell and Larcker (1981), is to compare the average variance extracted (AVE) and the squared correlation between any two constructs. To establish discriminant validity, a value of the AVE should be greater than a value of the squared correlation (Fornell and Larcker, 1981; Batra and Sinha, 2000). Table 12 shows

that values of AVE are considered acceptable. Thus, the analysis of measurement models demonstrates that measures used in this study are reliable, unidimensional, and valid.

Table 12. Discriminant validity assessment using Cronbach's α and AVE

Variables	1	2	3	4	5	6	7	8	9	10	11	12	13	α^*	AVE**
1. MAL	1.00													0.889	0.584
2. TRA	0.54	1.00												0.863	0.685
3. EMR	0.52	0.70	1.00											0.848	0.586
4. SQM	0.34	0.46	0.55	1.00										0.855	0.607
5. CUR	0.39	0.47	0.46	0.38	1.00									0.867	0.625
6. QDR	0.34	0.73	0.76	0.57	0.51	1.00								0.886	0.661
7. PSD	0.51	0.62	0.74	0.58	0.42	0.72	1.00							0.892	0.680
8. PRM	0.26	0.58	0.66	0.57	0.29	0.73	0.71	1.00						0.792	0.564
9. RPD	0.20	0.32	0.25	0.21	0.17	0.34	0.37	0.26	1.00					0.932	0.739
10. IPDI	0.31	0.26	0.41	0.30	0.22	0.31	0.43	0.46	0.38	1.00				0.934	0.742
11. RPCI	0.28	0.24	0.38	0.21	0.10	0.29	0.34	0.31	0.32	0.28	1.00			0.876	0.705
12. IPCI	0.22	0.36	0.54	0.42	0.20	0.46	0.51	0.65	0.15	0.37	0.37	1.00		0.890	0.733
13. ADMI	0.39	0.45	0.43	0.24	0.20	0.41	0.47	0.52	0.30	0.29	0.45	0.34	1.00	0.848	0.651

*: Cronbach's α

**: Average variance extracted (AVE)

5.2. Hypotheses testing

This section presents the results of the hypothesis testing. Research findings will be described focusing on two main issues: the relationship between QM practices and innovation and the interaction effects of moderating variables. Figure 4 shows a final structural model.

Figure 4. A final structural model

Hypotheses were tested using a latent variable model that included both latent variables and observed variables. Unlike the path analysis that assumes no measurement error, the latent variable model helps researchers not only to identify prediction error and measurement error, but also to accurately evaluate constructs and phenomena (Sila and Ebrahimpour, 2005). LISREL, using the maximum likelihood estimation, was employed to estimate coefficient and t-statistics. The estimate coefficient, noted by gamma (γ) and beta (β), represents the relative strength of the structural relationships between variables, while the *t*-statistic is a criterion to accept or reject a hypothesis (Gefen *et al.*, 2000). The gamma (γ) is related to paths linking an exogenous latent variable to an endogenous latent variable, while the beta (β) is associated with paths connecting

an endogenous latent variable to another endogenous latent variable. The t -value greater than 1.96 is significant at the 95% significance level, whereas the t -value greater than 2.58 is significant at the 99% significance level (Kaynak, 2003).

Tables 13 and 14 indicate the results of the tests of *the relationship between QM practices and innovation*. Overall results indicate 21 hypotheses were supported at the 95% or 99% significance level. The goodness of fit indices shows that the structural model fits the data: CFI = 0.98; RMSEA = 0.043; $\chi^2/df = 1714/1197 = 1.43$; NFI = 0.94; and NNFI = 0.98. It should be noted that all hypotheses related to management leadership (H1 – H5) were supported: between management leadership and training ($\gamma = 0.45$; t -value = 7.03); between management leadership and employee relations ($\gamma = 0.14$; t -value = 2.37); between management leadership and supplier quality management ($\gamma = 0.17$; t -value = 2.06); between management leadership and customer relations ($\gamma = 0.43$; t -value = 5.54); and between management leadership and product/service design ($\gamma = 0.18$; t -value = 2.82). Moreover, significant paths were found in relationships between other QM practices, such as between training and employee relations. These statistical significances supported the following hypotheses: H6, H7, H8, H9, H10, H11, H13, H14, H15, H16, and H22. Furthermore, the result showed that process management is a significant and direct predictor of five types of innovation, supporting H23 – H27. Further, it was found that impact of process management varies with the type of innovation. The impact of process management is less in the case of radical product innovation (coefficient: 0.41), when compared to other types of innovation: incremental product innovation (0.86), radical process innovation (0.79), incremental process innovation (1.06), and administrative innovation (0.81). In other words, effective process management positively impacts four types of innovation: incremental product innovation, radical process innovation, incremental process innovation, and

administrative innovation to a greater extent. Moreover, it was found that non-significant relationships between quality data/reporting and five types of innovation did not support H17 – H21. Supplier quality management was not significantly related to process management (Beta β = 0.09; t -value = 1.63) and did not support H12.

Table 13. Analysis results of the structural model

Path	Coefficient	<i>t</i> -value	Significance
H 1. Management leadership → Training	0.45	7.03	Significant**
H 2. Management leadership → Employee relations	0.14	2.37	Significant*
H 3. Management leadership → Supplier quality management	0.17	2.06	Significant*
H 4. Management leadership → Customer relations	0.43	5.54	Significant**
H 5. Management leadership → Product/service design	0.18	2.82	Significant**
H 6. Training → Quality data & reporting	0.38	3.81	Significant**
H 7. Training → Employee relations	0.56	6.60	Significant**
H 8. Employee relations → Quality data & reporting	0.59	5.18	Significant**
H 9. Employee relations → Product/service design	0.38	3.12	Significant**
H 10. Employee relations → Process management	0.23	2.22	Significant*
H 11. Supplier quality management → Product/service design	0.15	2.34	Significant*
H 12. Supplier quality management → Process management	0.09	1.63	Non-significant
H 13. Customer relations → Quality data & reporting	0.15	3.06	Significant**
H 14. Quality data & reporting → Supplier quality management	0.56	6.09	Significant**
H 15. Quality data & reporting → Product/service design	0.36	3.47	Significant**
H 16. Quality data & reporting → Process management	0.26	2.68	Significant**
H 17. Quality data & reporting → Radical product innovation	0.18	1.04	Non-significant
H 18. Quality data & reporting → Incremental product innovation	-0.23	-1.64	Non-significant
H 19. Quality data & reporting → Radical process innovation	-0.16	-0.92	Non-significant
H 20. Quality data & reporting → Incremental process innovation	-0.17	-1.16	Non-significant
H 21. Quality data & reporting → Administrative innovation	-0.07	-0.44	Non-significant
H 22. Product/service design → Process management	0.27	3.41	Significant**
H 23. Process management → Radical product innovation	0.41	1.97	Significant*
H 24. Process management → Incremental product innovation	0.86	4.95	Significant**
H 25. Process management → Radical process innovation	0.79	3.78	Significant**
H 26. Process management → Incremental process innovation	1.06	5.76	Significant**
H 27. Process management → Administrative innovation	0.81	4.38	Significant**
H 28. Behavioural QM practices → Mechanistic QM practices	1.60	7.94	Significant**

* $P < 0.05$: *t*-value is greater than 1.96

** $P < 0.01$: *t*-value is greater than 2.58

Table 14. Results of hypothesis testing

Hypothesis	Result
H 1. Management leadership will be positively associated with training.	Supported
H 2. Management leadership will be positively associated with employee relations.	Supported
H 3. Management leadership will be positively associated with supplier quality management.	Supported
H 4. Management leadership will be positively associated with customer relations.	Supported
H 5. Management leadership will be positively associated with product/service design.	Supported
H 6. Training will be positively associated with quality data & reporting.	Supported
H 7. Training will be positively associated with employee relations.	Supported
H 8. Employee relations will be positively associated with quality data and reporting.	Supported
H 9. Employee relations will be positively associated with product/service design.	Supported
H 10. Employee relations will be positively associated with process management.	Supported
H 11. Supplier quality management will be positively associated with product/service design.	Supported
H 12. Supplier quality management will be positively associated with process management.	Not Supported
H 13. Customer relations will be positively associated with quality data and reporting.	Supported
H 14. Quality data & reporting will be positively associated with supplier quality management.	Supported
H 15. Quality data & reporting will be positively associated with product/service design.	Supported
H 16. Quality data & reporting will be positively associated with process management.	Supported
H 17. Quality data & reporting will be positively associated with radical product innovation.	Not supported
H 18. Quality data & reporting will be positively associated with incremental product innovation.	Not supported
H 19. Quality data & reporting will be positively associated with radical process innovation.	Not supported
H 20. Quality data & reporting will be positively associated with incremental process innovation.	Not supported
H 21. Quality data & reporting will be positively associated with administrative innovation.	Not supported
H 22. Product/service design will be positively associated with process management.	Supported
H 23. Process management will be positively associated with radical product innovation.	Supported
H 24. Process management will be positively associated with incremental product innovation.	Supported
H 25. Process management will be positively associated with radical process innovation.	Supported
H 26. Process management will be positively associated with incremental process innovation.	Supported
H 27. Process management will be positively associated with administrative innovation.	Supported
H 28. Behavioural QM practices will be positively associated with mechanistic QM practices.	Supported
H 29. Firm size will moderate the relationship between QM and innovation.	Not supported
H 30. The duration of QM adoption will moderate the relationship between QM and innovation.	Not supported
H 31. Structural control will moderate the relationship between QM and innovation.	Not supported
H 32. Structural exploration will moderate the relationship between QM and innovation.	Not supported
H 33. Industry will moderate the relationship between QM and innovation.	Not supported

To further explore the relationship between QM practices and innovation, *indirect effects* were examined using LISREL. Table 15 shows the total effects and indirect effects of QM

practices on innovation. One of the important findings was that QM practices have a significant and indirect impact on innovation. In particular, there were significant and indirect links among three QM practices (management leadership, training, and employee relations) and all types of innovation. Other QM practices (supplier quality management and customer relations) partially and indirectly related to innovation. Further, although there was no significant and direct relationship between quality data and reporting and innovation, quality data and reporting had a significantly direct and indirect effect on process management. Through process management, quality data and reporting indirectly influenced four types of innovation, such as incremental product innovation. Moreover, the indirect effects of quality data and reporting on innovation were positive and significant, while the direct effects of quality data and reporting on innovation were negative and insignificant.

Table 15. Total effects and indirect effects

<i>Effect from</i>	<i>Effect to Process management</i>		Radical product innovation		Incremental product innovation		Radical process innovation		Incremental process innovation		Administrative innovation	
	Total	Indirect	Total	Indirect	Total	Indirect	Total	Indirect	Total	Indirect	Total	Indirect
Management leadership	0.41***	0.41***	0.25***	0.25***	0.24***	0.24***	0.25***	0.25***	0.35***	0.35***	0.30***	0.30***
Training	0.49***	0.49***	0.33***	0.33***	0.26***	0.26***	0.28***	0.28***	0.40***	0.40***	0.36***	0.36***
Employee relations	0.59***	0.36***	0.35***	0.35***	0.37***	0.37***	0.37***	0.37***	0.53***	0.53***	0.44***	0.44***
Supplier quality management	0.13**	0.04*	0.05	0.05	0.11**	0.11**	0.10**	0.10**	0.14**	0.14**	0.11**	0.11**
Customer relations	0.07***	0.07***	0.05**	0.05**	0.02	0.02	0.03	0.03	0.04**	0.04**	0.04**	0.04**
Quality data & reporting	0.43***	0.17***	0.36***	0.18*	0.14	0.37***	0.18	0.34***	0.29***	0.46***	0.29***	0.35***
Product/Service design	0.27***	0.00	0.11*	0.11*	0.24***	0.24***	0.22***	0.22***	0.29***	0.29***	0.22***	0.22***
Process management	0.00	0.00	0.41**	0.00	0.86***	0.00	0.79***	0.00	1.06***	0.00	0.81***	0.00

* $P < 0.10$: t -value is greater than 1.65

** $P < 0.05$: t -value is greater than 1.96

*** $P < 0.01$: t -value is greater than 2.58

Process management has direct effect on five types of innovation, and there is no indirect effect.

Quality data & reporting has direct and negative effects on innovation (See Table 13). However, the links are statistically insignificant.

Additionally, *paths, not included in a set of hypotheses*, were examined to identify estimated coefficients and *t*-values. Although the literature reported no significant paths, it was interesting to test whether all QM practices have a direct impact on innovation. Thirty direct paths (e.g., management leadership → radical product innovation; customer relations → incremental process innovation) were added to the proposed structural model. The goodness of fit indices showed that the model has a good fit to the data: CFI = 0.98; RMSEA = 0.042; $\chi^2/df = 1660.64/1167 = 1.42$; NFI = 0.94; and NNFI = 0.98. Four significant paths were additionally found to be statistically significant paths. These paths were as follows: between product/service design and radical product innovation ($\beta = 0.41$; *t*-value = 2.29); between management leadership and radical process innovation ($\beta = 0.25$; *t*-value = 2.03); between employee relations and incremental process innovation ($\beta = 0.50$; *t*-value = 2.71); and between management leadership and administrative innovation ($\beta = 0.28$; *t*-value = 2.57). These results are consistent with a few studies' findings. For example, using data from 252 firms, Feng *et al.* (2006) found a significant relationship between management leadership and innovation; and between employee relations and innovation. Hoang *et al.* (2006), in an empirical study of 102 machinery and instrument firms, concluded that there are significant relationships between employee relations and innovation; and between management leadership and innovation. Similarly, Perdomo-Ortiz *et al.* (2006), in an empirical study, confirmed a significant positive relationship between product/service design and innovation.

To test for *the relationship between behavioural QM practices and mechanistic QM practices*, a second-order model was developed (See Appendix H). The model was composed of two second-order factors: one for behavioural QM practices (management leadership, training, employee relations, supplier quality management, and customer relations) and the other for

mechanistic QM practices (quality data/reporting, product/service design, and process management). For example, the second level factor represented a behavioural QM practice, which also included the first level sub-factors, such as management leadership. Further, the behavioural QM practice was considered to be an exogenous construct, while the mechanistic QM practice was regarded as an endogenous construct. A second-order factor analysis using LISREL was performed to examine the causal relationship between behavioural and mechanistic QM practices (Jöreskog and Sörbom, 1996; Marsh and Hocevar, 1988). The goodness of fit indices demonstrated that the model fit the data very well: CFI = 0.99; RMSEA = 0.039; $\chi^2/df = 625.89/455 = 1.38$; NFI = 0.99; and NNFI = 0.99. The estimate coefficient for the path between behavioural QM practices and mechanistic QM practices was statistically significant ($\gamma = 3.20$ and t -value 3.76). Thus, the hypothesis (H28) was supported.

To test for the *interaction effects of moderating variables*, a multi-group analysis (also called a multi-sample analysis) using LISREL was performed. The analysis aimed at expanding the research findings of the proposed model by examining whether a covariance of a variable is equal for different groups (Jöreskog and Sörbom, 1996). A two-stage approach was employed. First, the sample was divided into two groups in terms of each moderating variable: high technology industry vs. low technology industry; small and medium-sized company vs. large-sized company; adoption for less than three years vs. adoption for more than three years; high control structure vs. low control structure; and high exploration structure vs. low exploration structure.

The classification of high vs. low technology industry was based on classifications proposed by Kaynak and Hartley (2005), who found that high technology firms operate mainly in the following seven industries: primary metal manufacturing; machinery manufacturing;

transportation equipment manufacturing; chemical manufacturing; fabricated metal product manufacturing; computer and electronic product manufacturing; and electrical equipment, appliance and component manufacturing. High technology firms refer to organizations that allocate heavy resources to research and development and produce products or services that have a short life-cycle in high uncertain environment (Qian & Li, 2003).

Further, small- and medium-sized companies employ up to 500 workers, while the large-sized companies employ more than 500 (Debus, 2005). The classification of the QM adoption period was related to whether a company has adopted the ISO 9001 certification less than three years or more than three years (Powell, 1996; Zadry and Yusof, 2006). Based on guidance proposed by Douglas and Judge (2001), organizational structure was split into two sub-features: structural control and structural exploration. Again, structural control was divided into high control structure and low control structure, whereas the exploration structure was split into high exploration structure and low exploration structure (Douglas and Judge, 2001). As data for the organizational structure was collected using multiple questions on a seven-point Likert-type scale, respondents' scores were averaged first and grouped into two groups: a low group and a high group. With respect to the structural control, the high control group scored from 1 to 4, while the low control group scored more than 4 to 7. In contrast, in terms of the structural exploration, the high exploration group scored more than 4 to 7, while the low exploration group scored from 1 to 4.

In the second-stage for exploring interaction effects, a proposed structural model was tested separately in each group to identify a parameter estimate of critical paths (e.g., process management → administrative innovation; process management → incremental process innovation). This study focused on five paths that show direct relationships between process

management and five types of innovation. This is because process management is considered to be the most significant practice that directly leads to innovation. Figure 5 shows a structural model focusing on the five paths.

Figure 5. A structural model focusing on five paths

Next, to examine equality constraints between two groups, an unconstrained model and an equality constrained model were developed (Jöreskog and Sörbom, 1996). The unconstrained model estimated all hypothesized paths freely, while the equality constrained model specified a single path to equality across groups (Brockman *et al.*, 2006; Neill, 2009). To interpret analysis results, a difference of χ^2 values of both models was compared. According to the literature, the interaction effect of a moderating variable is significant at the 0.05 level if the difference of χ^2 values is 3.84 or greater (Neill, 2009; Brockman *et al.*, 2006).

Table 16 shows the analysis results of the multi-group analysis. The differences of χ^2 between unconstrained models and equality constrained models ranged from 0 to 3.06. Most χ^2 values were less than 3.84. Hypotheses 29 – 33 were not supported since the hypotheses are not

significant at the 95% or 99% significance level. It can be interpreted that five moderating variables (firm size, the duration of QM adoption, structural control, structural exploration, and industry) do not have interaction effects on the relationship between QM practices and innovation. To fully explore the differences between groups, parameter estimates of five paths were individually investigated. One of the most important findings was that process management is a significant predictor of innovation in various groups. For instance, process management was significantly related to radical product innovation in both groups: companies that had adopted QM for up to three years and companies that had adopted QM for more than three years. Similarly, the path linking process management to incremental product innovation was statistically significant in these groups: high control and low control groups; high exploration and low exploration groups; and high technology and low technology industries. Based on these analysis results, managerial implications will be discussed in the next section.

Table 16. Multi-group analysis result to test interaction effects of moderating variables

Path	Moderating variable	χ^2 of the unconstrained model	χ^2 of the equality constrained model	$\Delta\chi^2$ (df) ^a	Coefficient (t-value)
Process management → Radical product innovation	Firm size	4816.42	4816.41	0.01	Small & medium-sized firms: 0.29 (1.29) Large-sized firms: 0.62 (1.22)
	Duration of QM adoption	4179.71	4179.70	0.01	Less than 3 years: -0.83** (-2.62) More than 3 years: 0.81** (2.85)
	Structural control	3450.75	3450.75	0.00	High control: 0.55 (1.79) Low control: 0.13 (0.45)
	Structural exploration	4116.67	4116.47	0.20	High exploration: 0.37 (1.56) Low exploration: 0.08 (0.25)
	Industry	3461.08	3461.03	0.05	High technology industry: 0.19 (0.72) Low technology industry: 0.88* (2.38)
Process management → Incremental product innovation	Firm size	4816.42	4815.48	0.94	Small & medium-sized firms: 0.85** (4.67) Large-sized firms: 0.72 (1.69)
	Duration of QM adoption	4179.71	4177.45	2.26	Less than 3 years: -0.11 (-0.51) More than 3 years: 1.17** (4.61)
	Structural control	3450.75	3450.59	0.16	High control: 0.89** (3.53) Low control: 0.82** (3.33)
	Structural exploration	4116.67	4114.15	2.52	High exploration: 0.91** (4.68) Low exploration: 0.30 (0.95)
	Industry	3461.08	3459.37	1.71	High technology industry: 0.57** (3.06) Low technology industry: 1.51** (3.79)
Process management → Radical process innovation	Firm size	4816.42	4815.53	0.89	Small & Medium-sized firm: 0.62** (2.82) Large-sized firms: 1.73** (2.60)
	Duration of	4179.71	4176.65	3.06	Less than 3 years: 0.04 (0.12)

Path	Moderating variable	χ^2 of the unconstrained model	χ^2 of the equality constrained model	$\Delta\chi^2$ (df) ^a	Coefficient (<i>t</i> -value)
Process management → Incremental process innovation	QM adoption				More than 3 years: 0.91** (3.49)
	Structural control	3450.75	3450.74	0.01	High control: 0.90** (2.85) Low control: 0.80** (2.75)
	Structural exploration	4116.67	4116.20	0.47	High exploration: 0.84** (3.42) Low exploration: 0.22 (0.74)
	Industry	3461.08	3461.02	0.06	High technology industry: 0.56* (2.41) Low technology industry: 1.31** (3.00)
	Firm size	4816.42	4816.42	0.00	Small & medium-sized firms: 1.05** (5.56) Large-sized firms: 0.84 (1.61)
	Duration of QM adoption	4179.71	4178.95	0.76	Less than 3 years: 0.77** (3.20) More than 3 years: 0.92** (3.92)
	Structural control	3450.75	3450.17	0.58	High control: 0.95** (3.49) Low control: 1.26** (4.83)
	Structural exploration	4116.67	4116.56	0.11	High exploration: 0.93** (4.74) Low exploration: 0.98** (3.04)
	Industry	3461.08	3460.99	0.09	High technology industry: 0.97** (4.35) Low technology industry: 1.23** (3.60)
	Firm size	4816.42	4815.47	0.95	Small & medium-sized firms: 0.59** (3.12) Large-sized firms: 1.68** (2.67)
Process management → Administrative innovation	Duration of QM adoption	4179.71	4179.71	0.00	Less than 3 years: 0.19 (0.64) More than 3 years: 0.88** (3.65)
	Structural control	3450.75	3450.57	0.18	High control: 0.83** (3.05) Low control: 0.79** (3.04)
	Structural exploration	4116.67	4116.20	0.47	High exploration: 0.83** (3.80) Low exploration: 0.42 (1.56)

Path	Moderating variable	χ^2 of the unconstrained model	χ^2 of the equality constrained model	$\Delta\chi^2$ (df) ^a	Coefficient (<i>t</i> -value)
	Industry	3461.08	3460.60	0.48	High technology industry: 0.83** (3.28) Low technology industry: 0.95** (3.11)

$\Delta\chi^2$ (df) ^a: The difference of χ^2 values between the unconstrained model and the equality constrained model

* $P < 0.05$; *t*-value is greater than 1.96; ** $P < 0.01$; *t*-value is greater than 2.58

6. Discussion and implications

This study explores the contribution of QM practices to innovation through an empirical analysis. The analysis demonstrates strong support for the relationship between QM practices and innovation. The results of the latent variable model analysis and the multi-group analysis using LISREL indicate that 22 out of 33 hypotheses are supported. The supported hypotheses clearly show how QM practices through process management have statistically significant direct or indirect effects on performance. Moreover, there is no significant and direct relationship between supplier quality management and process management. This finding is consistent with those of other studies (e.g., Flynn *et al.*, 1995; Sila and Ebrahimpour, 2005). An additional test of indirect effects, however, demonstrates that supplier quality management also has an indirect and significant effect on innovation. Similarly, while five hypotheses related to quality data and reporting are not supported, the analysis of indirect and total effects indicates that quality data and reporting is significantly associated with process management, impacting innovation indirectly. Hypotheses related to moderating variables are not supported, indicating that there is no interaction effect of the moderating variables on the relationship between QM practices and innovation. This analysis leads to three important findings and managerial implications.

The *first finding* is that QM practices have significant direct or indirect effects on innovation. The impacts of QM practices could be achieved if an organization implements a set of QM practices, not just a single or a few QM practices. This is because QM practices are interrelated to each other. For instance, training is significantly related to quality data and reporting, whereas quality data and reporting influences product/service design and process

management. This finding is consistent with those of earlier studies. Using data from 130 R&D divisions of manufacturing firms, Prajogo and Hong (2008) found that there is a significant and positive relationship between a set of QM practices and product innovation. Similarly, Martinez-Costa and Martinez-Lorente (2008), in a study of 451 manufacturing and non-manufacturing firms, found a positive and significant relationship between QM practices and product and process innovation. In an empirical study of 407 plants in the automobile industry, Ahire and Ravichandran (2001) underscored that QM should be implemented in an integrated fashion, not a cherry-picking manner. Similarly, Kaynak (2003), in a study of 214 manufacturing and service companies, found that a set of QM practices are significantly associated with performance. As Kaynak (2003) pointed out, the validation of the interdependence of QM practices should be emphasized to correctly understand the effects of QM practices on performance.

One *implication of this finding* is that top management should encourage employees to understand the causal relationship among QM practices and implement the practices in a comprehensive manner. Further, it will be useful for companies to identify the current status and develop strategies to improve some weaknesses by using the causal map. For example, to improve organizational capabilities for quality data and reporting, a company might invest in providing its employees with various training programs, working to motivate employee involvement in QM activities and establishing a close relationship with its customers. Therefore, investments in key practices may allow a company to efficiently improve its performance.

The *second finding* is that management leadership and process management should be considered as the most important practices in fostering innovation. This study shows that management leadership is a significant predictor of other QM practices and innovation. The analysis result indicates that management leadership has a direct effect on five other practices:

training, employee relations, supplier quality management, customer relations, and product/service design. Management leadership is also positively and indirectly related to innovation. One interpretation is that management leadership plays a key role in implementing QM and producing innovation. Moreover, this study confirms a positive and direct role for process management in improving innovation. The analysis result shows that process management mediates the effects of QM practices (quality data and reporting, employee relations, supplier quality management, and product/service design) on five types of innovation. In particular, it was found that impact of process management varies with the type of innovation. The impact of process management is less in the case of radical product innovation, when compared to other types of innovation: incremental product innovation, radical process innovation, incremental process innovation, and administrative innovation. These findings are related to those of prior research. For example, Flynn *et al.* (1995), in a study of 42 manufacturing plants, reported that top management support is significantly related to customer relationship, supplier relationship, workforce management, work attitude, and product design process. Flynn *et al.* (1995) also found a significant relationship between process management and performance. Similarly, Hoang *et al.* (2006), in a study of 204 manufacturing and service companies, concluded that management leadership and process management showed significant and positive impacts on innovation.

Further, the results indicate that behavioural practices (e.g., leadership and employee relations) are significantly associated with mechanistic practices (e.g., process management and product/service design). A possible interpretation for this finding is that the success of TQM is based on a solid foundation of the behavioural aspects of QM practices (Zaho *et al.*, 2004). It can be argued that developing the behavioural QM practices is a starting point in achieving

innovation. This argument is supported by current studies. In an empirical study of 252 firms, Feng *et al.* (2006) found that the behavioural practices are significantly related to innovation. Hoang *et al.* (2006), based on their empirical study in 204 manufacturing and service firms, showed a statistical evidence for supporting the relationship between the behavioural practices (e.g., leadership and people management) and innovation.

One *implication of these findings* is that a company should devote attention to developing two practices: management leadership and process management. While management leadership is a baseline and a main foundation for enhancing other QM practices, process management has a direct effect on various types of innovation. Without top management and managers' commitment, it would be difficult to have an appropriate environment for generating the mechanistic practices. Similarly, to create innovation radically or incrementally, it may be imperative for companies to invest in the improvement of organizational processes. This suggestion will provide guidance for a company when investing its resources and changing its strategies.

The *third finding* is that the impacts of QM practices on innovation are not dependent on contextual features: firm size, the duration of QM adoption, structural control, structural exploration, and industry. Operations management researchers produced inconsistent findings of these aspects on the effectiveness of QM. While proponents of QM argued that the performance of QM can be universally available in any type of organization, some researchers found that the benefits of QM are contingent on the organizational context (e.g., Powell, 1995; Sousa and Voss, 2002). The findings of this study, however, demonstrate that there is no statistically significant difference in companies that have different contexts. However, the findings in this study would not mean that contextual factors are not important when implementing QM. Instead, one

plausible explanation is that organizational efforts and attention might be more important to innovation than the organizational context. The finding of this study is consistent with findings of earlier empirical studies. For instance, Sila (2007), in a study of 302 manufacturing and service companies, found no evidence to support the argument that the relationship between QM and performance is context-dependent.

One *implication of these findings* is that a company should understand that the contextual factors (e.g., the duration of adoption of QM or the type of industry) are not sufficient to generate the impacts of QM on innovation. Organizational efforts to continually improve processes and systems require more attention. For example, while a company adopted and implemented QM practices for more than three years, the company might fail to achieve performance unless the company makes an effort to continually improve QM practices. Similarly, many companies with a certified ISO 9001 quality management system do not achieve superior performance through adopting ISO 9001. This is because top management was not involved in the organizational efforts and employees considered ISO 9001 as a paper-driven tool that lacks flexibility in relation to other management systems (Hashem and Tann, 2007; Zeng *et al.*, 2007). Therefore, a company may need to pay attention to its efforts and corresponding QM practices.

7. Conclusion and limitations

This study examines how QM practices impact on innovation. Based on the extensive literature review, a theoretical model is proposed that contains eight QM practices and five types of innovation. To test the causal relationship, data were collected from a sample of 223 ISO 9001 certified manufacturing or service firms. The statistical analysis, using the SEM approach, shows that all QM practices are interrelated with each other, influencing innovation directly or indirectly. This study also demonstrates that management leadership is a triggering factor for the development of other practices, such as training. In particular, process management has a significant and direct effect on all types of innovation. To further expand the boundary of earlier studies, the interaction effect of moderating variables, such as firm size and industry, is examined. The analysis using the multi-group analysis indicates that there is no significant effect of the moderating variables on the relationship between QM and innovation.

A few limitations of this study should be recognized, providing researchers with future research opportunities. Respondents for this study are ISO 9001 certified companies. The companies fit the research purpose because they are familiar with terminologies and concepts of QM practices. However, other QM intensive companies, which were awarded quality improvement awards such as the MBNQA or the EFQA, might have been left out of this study. It would be promising to replicate this research using data collected from companies that had been awarded the MBNQA or the EFQA but are not ISO 9001 certified. A second limitation is the use of cross-sectional data. Although the research is focused on examining the impact of QM on innovation across various organizations, it would be valuable to conduct a longitudinal study within organizations. This attempt would verify the finding of this research and improve

understanding of the relationship of QM to innovation. While this study collected data based on respondents' perceptual judgment, considering their performance within a company, there is little attempt to compare their achievements with other competitors in a similar industry. There is also no quantitative measurement item to evaluate innovation. Though this study adopts measurement items from the literature, future researchers need to develop more objective and comprehensive measurement items for extending this research.

Despite these limitations, this study contributes to the development of the literature in the following five ways. First, it helps academics and practitioners understand how and why QM practices lead to innovation. Earlier studies answered "which QM practice is related to innovation" not "how QM practice leads to innovation." In other words, earlier studies were limited to simply identifying a list of QM practices that were related to innovation. Such a narrow view might be a reason for producing inconsistent findings about the impacts of QM on innovation. Unlike the previous studies, this study investigates linkages among QM practices and clearly shows the casual relationship of how a QM practice interacts with other QM practices to finally lead to innovation.

Second, this study provides empirical evidence about the relationship between behavioural QM practices and mechanistic QM practices. The literature calls for more research on the relationship (Sousa and Voss, 2002; Rahman, 2004). However, there is a lack of theory development underlying the correlation (e.g., Powell 1995; Feng *et al.*, 2006; Samson and Terziovski, 1999; Hoang *et al.*, 2006). To expand the current knowledge, this study examines the relationship and concludes that behavioural QM practices have a direct effect on mechanistic QM practices. This will allow practitioners and academics to understand why behavioural QM

practices should be considered as foundational to implement mechanistic QM practices and how mechanistic QM practices can be generated through behavioural QM practices.

Third, this study makes a significant contribution to enhancing a better understanding of the relationship between QM practices and various types of innovation. This study examines the links between QM practices and five different types of innovation, such as radical incremental product innovation and administrative innovation. It is essential to explore the multidimensional aspects of innovation because for companies to achieve a sustainable competitive advantage, they need to understand the multiple types of innovation and balance between innovation efforts for existing customers and emerging ones (Tushman and O'Reilly, 1996; Grover *et al.*, 2007; Corso *et al.*, 2007; March, 1991). Theoretical support for this argument can be found in the literature – the relative imbalance between the innovative capabilities is negatively related to organizational performance (e.g., He and Wong, 2004; Baker and Sinkula, 2007; Danneels, 2004).

Fourth, this study expands the boundaries of previous studies by exploring the interaction effects of contextual variables, such as industry and firm size. In the operations management literature, researchers devoted little attention to examine the contextual factors (Nair, 2006; Sousa and Voss, 2002). However, understanding the moderating variables is very useful in highlighting the importance of QM practices in different situations. For instance, a service company might argue that its poor QM performance is caused by contextual factors. The company still regards QM as a management tool only for manufacturing companies. However, the findings of this study demonstrate that there is no significant interaction effect of the moderating variables in companies that are in different industries, have different number of employees, have different organizational structures, or adopted QM for a different duration. This

result provides empirical evidence for supporting the argument that any type of company can achieve better performance using quality-based tools and concepts.

Finally, this study contributes to the literature on innovation by providing a comparison framework for radical, incremental, and administrative innovations. The extant literature has put little emphasis on describing the characteristics of the types of innovation in such depth. In this study, the characteristics are analyzed in terms of various dimensions, such as an objective, a level of change, and an output. The attempt will enable managers to understand features of innovation and efficiently manage a specific type of innovation. For example, managers can understand that an organic structure and a bottom-up approach are required to generate radical innovation, whereas a mechanistic structure and a bottom-up approach are needed to produce incremental innovation. Similarly, it will be helpful for managers to identify what level of risks they should take for creating different types of innovation; what kind of output of innovation will be expected.

Appendixes

Appendix A. Research model of Kaynak (2003)

Appendix B. Variables and measures

Variables	Measures
QM Practices	Please indicate the level of the following items in your organization over the past 3 years.
Management leadership	(adapted from Kaynak, 2003; Saraph <i>et al.</i> , 1989)
MAL 1	<ul style="list-style-type: none"> Our top management (top organization executive and major department heads) evaluates quality performance.
MAL 2	<ul style="list-style-type: none"> Our department heads participate in the quality improvement process.
MAL 3	<ul style="list-style-type: none"> Our top management has objectives for quality performance.
MAL 4	<ul style="list-style-type: none"> Our top management has laid down a comprehensive goal-setting process for quality.
MAL 5	<ul style="list-style-type: none"> Quality issues are reviewed in organizational top management meetings.
MAL 6	<ul style="list-style-type: none"> Our top management considers quality improvement as a way to increase profits.
Training	(adapted from Kaynak, 2003; Saraph <i>et al.</i> , 1989)
TAL 1	<ul style="list-style-type: none"> Our organization provides employees with specific work skills training (technical and vocational).
TAL 2	<ul style="list-style-type: none"> Our organization provides employees with quality-related training.
TAL 3	<ul style="list-style-type: none"> Our organization provides managers and supervisors with quality-related training.
Employee relations	(adapted from Kaynak, 2003; Saraph <i>et al.</i> , 1989)
EMR 1	<ul style="list-style-type: none"> Our organization provides employees with feedback on their quality performance.
EMR 2	<ul style="list-style-type: none"> Hourly/non-supervisory employees participate in quality decisions.
EMR 3	<ul style="list-style-type: none"> Building quality awareness among employees is ongoing.
EMR 4	<ul style="list-style-type: none"> Employees recognize superior quality performance.
Supplier quality management	(adapted from Kaynak, 2003; Saraph <i>et al.</i> , 1989)
SQM 1	<ul style="list-style-type: none"> Our organization maintains long-term relationships with suppliers.
SQM 2	<ul style="list-style-type: none"> Our organization has reduced the number of suppliers since implementing quality management and/or JIT purchasing.
SQM 3	<ul style="list-style-type: none"> Our organization selects suppliers based on quality rather than price or delivery schedule in order to improve organizational performance.
SQM 4	<ul style="list-style-type: none"> Our organization evaluates suppliers according to quality, delivery performance, and price, in order to improve organizational performance.
SQM 5	<ul style="list-style-type: none"> Our organization has a thorough supplier rating system.
SQM 6	<ul style="list-style-type: none"> Our suppliers are involved in our product/service development process.
Customer relations	(adapted from Flynn <i>et al.</i> , 1995; Zu <i>et al.</i> , 2008)
CUR 1	<ul style="list-style-type: none"> We frequently are in close contact with our customers.
CUR 2	<ul style="list-style-type: none"> Our employees know our customers.
CUR 3	<ul style="list-style-type: none"> Our customers give us feedback on quality and delivery performance.
CUR 4	<ul style="list-style-type: none"> Our customers visit our office or workplace.
Quality data and reporting	(adapted from Kaynak, 2003; Saraph <i>et al.</i> , 1989)
QDR 1	<ul style="list-style-type: none"> Quality data (for example, error rates, defect rates, scrap, and defects) is available in our organization.
QDR 2	<ul style="list-style-type: none"> Such quality data is timely.
QDR 3	<ul style="list-style-type: none"> Such quality data (for example, cost of quality, defects, errors, scrap, etc.) is used as a tool to manage quality.

Variables	Measures
QDR 4	<ul style="list-style-type: none"> Quality procedures are available to ensure the reliability and improvement of data gathering.
Product/service design	(adapted from Kaynak, 2003; Saraph <i>et al.</i> , 1989)
PSD 1	<ul style="list-style-type: none"> Our organization conducts a thorough review of new product/service design before the product/service is produced and marketed.
PSD 2	<ul style="list-style-type: none"> Our departments fully participate in the product/service development process.
PSD 3	<ul style="list-style-type: none"> The quality of new products/services is emphasized in relation to cost or schedule objectives.
PSD 4	<ul style="list-style-type: none"> Productivity is considered during the product/service design process.
Process management	(adapted from Kaynak, 2003; Saraph <i>et al.</i> , 1989)
PRM 1	<ul style="list-style-type: none"> Inspection, review, or checking of work is automated.
PRM 2	<ul style="list-style-type: none"> We usually meet the production schedule everyday.
PRM 3	<ul style="list-style-type: none"> Our work processes are automated.
PRM 4	<ul style="list-style-type: none"> Quality techniques (e.g., statistical techniques) are used in order to reduce variance in processes.
Innovation	Please indicate the level of the following items over the past 3 years in your organization.
Radical product innovation	(adapted from Herrmann, <i>et al.</i> , 2007)
RPDI 1	<ul style="list-style-type: none"> Our new products differ substantially from our existing products.
RPDI 2	<ul style="list-style-type: none"> We introduce radical product innovations into the market more frequently than our competitors.
RPDI 3	<ul style="list-style-type: none"> Our percentage of radical product innovations in the product range is significantly higher compared to the competition.
RPDI 4	<ul style="list-style-type: none"> The percentage of total sales from radical product innovations is up substantially.
RPDI 5	<ul style="list-style-type: none"> We are well known by our customers for radical product innovations.
Incremental product innovation	(adapted from Herrmann, <i>et al.</i> , 2007; Valle and Vázquez-Bustelo, 2009)
IPDI 1	<ul style="list-style-type: none"> Our new products differ slightly from our existing products.
IPDI 2	<ul style="list-style-type: none"> We introduce incremental product innovations into the market more frequently than our competitors.
IPDI 3	<ul style="list-style-type: none"> Our percentage of incremental product innovations in the product range is significantly higher compared to the competition.
IPDI 4	<ul style="list-style-type: none"> The percentage of total sales from incremental product innovations is up substantially.
IPDI 5	<ul style="list-style-type: none"> We are well known by our customers for incremental product innovations.
Radical process innovation	(adapted from Reichstein and Salter, 2006; Huergo and Jaumandreu, 2004)
RPCI 1	<ul style="list-style-type: none"> Our organization has introduced new or significantly improved machinery and equipment for producing products or services.
RPCI 2	<ul style="list-style-type: none"> Our organization has introduced new or significantly modified productive processes for producing products or services.
RPCI 3	<ul style="list-style-type: none"> Our organization has introduced new or significantly improved information technologies for producing products or services.
Incremental process innovation	(adapted from Reichstein and Salter, 2006; Huergo and Jaumandreu, 2004; Jansen <i>et al.</i> , 2006)
IPCI 1	<ul style="list-style-type: none"> Our organization introduced minor or incrementally improved machinery and equipment

Variables	Measures
IPCI 2	for producing products or services. <ul style="list-style-type: none"> Our organization introduced minor or incrementally modified productive processes for producing products or services.
IPCI 3	<ul style="list-style-type: none"> Our organization introduced minor or incrementally improved information technologies for producing products or services.
Administrative innovation	(adapted from Weerawardena, 2003; Kimberly and Evanisko, 1981)
ADMI 1	<ul style="list-style-type: none"> Our organization implemented new or improved existing computer-based administrative applications.
ADMI 2	<ul style="list-style-type: none"> Our organization implemented new or improved existing employee reward/training schemes.
ADMI 3	<ul style="list-style-type: none"> Our organization implemented new or improved existing structures such as project team or departmental structures, within or in-between existing structures.
ADMI 4	<ul style="list-style-type: none"> Our organization obtained new financing sources.
Moderating variables	
Firm size	(adapted from Lehman, 1986; Terziovski <i>et al.</i> , 1997) <ul style="list-style-type: none"> How many employees do you have in your organization? Fewer than 50; between 50 and 500; over 500.
The duration of QM adoption	(adapted from Powell, 1995) <ul style="list-style-type: none"> For how many years has your organization maintained the ISO 9000 certification? Less than 3 years; more than 3 years; not applicable.
Organizational structure – Structural exploration	(adapted from Douglas and Judge, 2001) Please indicate the extent of the following items apply in your organization. 1 represents the first statement in each pair, and 7 represents the second statement, with 4 as the midpoint between the two choices. <ul style="list-style-type: none"> Choice 1: Highly structured channels of communication and highly restricted access to important financial and operating information. Choice 2: Open channels of communication with important financial and operating information flowing quite freely throughout the organization. Choice 1: A strong emphasis on holding fast to true and tried management principles regardless of any changes in business conditions. Choice 2: A strong emphasis on adapting freely to changing circumstances without too much concern for past practices.
Organizational structure – Structural control	(adapted from Douglas and Judge, 2001) <ul style="list-style-type: none"> Choice 1: Strong emphasis on always getting personnel to follow the formally laid down procedures. Choice 2: Strong emphasis on getting things done even if this means disregarding formal procedures. Choice 1: Tight formal control of most operations by means of sophisticated control and information systems. Choice 2: Loose, informal control; heavy dependence on informal relationships and cooperation for getting work done. Choice 1: Strong emphasis on getting line and staff personnel to adhere closely to formal job descriptions. Choice 2: Strong tendency to let requirements of the situation and the individual's personality define proper on-job behavior.
Industry	(adapted from Kaynak and Hatley, 2005) <ul style="list-style-type: none"> What type of industry is your organization in? Service; Chemical manufacturing; Primary metal manufacturing; Fabricated metal product manufacturing; Machinery manufacturing; Computer and electronic product manufacturing; Transportation equipment manufacturing; Electrical equipment, appliance, and component manufacturing; Other.

Appendix C. Variables and definitions

Variables	Definitions	Sources
Management leadership	The extent to which top management establishes quality goals and strategies, allocates resources, participates in quality improvement efforts, and evaluates quality performance	Saraph <i>et al.</i> (1989)
Training	The extent to which an organization provides employees with statistical training, job-related skill training, and quality-oriented training, such as quality techniques	Saraph <i>et al.</i> (1989)
Employee relations	The extent to which employees are involved in quality efforts, participate in quality decisions, have responsibilities for quality, recognize superior quality performance, handle quality issues, and improve the general awareness about quality	Saraph <i>et al.</i> (1989)
Supplier quality management	The extent to which an organization depends on fewer suppliers, is interdependent with suppliers, emphasizes quality rather than price in purchasing policy, and supports suppliers in product development	Saraph <i>et al.</i> (1989)
Customer relations	The extent to which an organization emphasizes understanding customer needs	Ahire and Ravichandran (2001)
Quality data and reporting	The extent to which an organization uses quality data, uses feedback of quality data to employees for problem solving, regularly measures quality, and evaluates employees based on quality performance	Saraph <i>et al.</i> (1989)
Product/service design	The extent to which all departments are involved in design reviews; an organization emphasizes productivity; an organization makes specifications clear; an organization highlights quality, not roll-out schedule; and an organization avoids frequent redesigns	Saraph <i>et al.</i> (1989)
Process management	The extent to which an organization clarifies process ownership, boundaries, and steps; an organization relies on less inspection; employees use quality techniques and automation; employees use fool-proof process design; and employees conduct self-inspection, preventive maintenance, and automated testing	Saraph <i>et al.</i> (1989)
Radical product innovation	Innovation associated with the introduction of products (or services) that incorporate substantially different technology from existing products	Herrmann, <i>et al.</i> (2007); Chandy and Tellis (1998); Valle and Vázquez-Bustelo (2009); Jansen <i>et al.</i> (2006); Martinez-Costa & Martinez-Lorente (2008)
Incremental product innovation	Innovation associated with the introduction of products (or services) that provide new features, improvements, or benefits to the existing technology in the existing market	Garcia and Calantone (2002); Chandy and Tellis

Variables	Definitions	Sources
Radical process innovation	Innovation associated with the application of new or significantly improved elements into an organization's production or service operations - input materials, equipment, and work and information flow mechanisms - with the purpose of accomplishing lower costs and/or higher product quality	(1998); Valle and Vázquez-Bustelo (2009); Jansen <i>et al.</i> (2006); Martinez-Costa & Martinez-Lorente (2008)
Incremental process innovation	Innovation associated with the application of minor or incrementally improved elements into an organization's production or service operations - input materials, equipment, and work and information flow mechanisms - with the purpose of accomplishing lower costs and/or higher product quality	Reichstein and Salter (2006); Huergo and Jaumandreu (2004); Ettlie (1983)
Administrative innovation	Innovation associated with the application of new ideas to improve organizational structures, routines, systems, and processes pertaining to the social structure of an organization	Gaignon <i>et al.</i> (2002); Reichstein and Salter (2006); Huergo and Jaumandreu (2004); Ettlie (1983)
Structure control and structural exploration	Organizational structure is divided into structural control and structural exploration. <ul style="list-style-type: none"> • The structural control is related to larger and more centralized structure with tight processes and cultures. High control-oriented organizations have a structured channel of communication and restrain the free flow of information. • The structural exploration is associated with small and decentralized structure with loose processes. High exploration organizations encourage employees to be involved in open and extensive interpersonal channels of communication. 	Weerawardena (2003); Loh and Venkatraman (1992); Damanpour (1987); Elenkov <i>et al.</i> (2005); Daft (1978)
Firm size	The number of employee in an organization: small (less than 50), medium (between 50 and 500), vs. large (over 500).	Douglas and Judge (2001); Hoffman and Hegarty (1993); Benner and Tushman (2003); Cooper (1998); Abrunhosa and Moura E Sá (2008)
The duration of QM adoption	Period for which an organization has obtained the ISO 9001 certification: Less than 3 years vs. more than 3 years.	Debus (2005)
		Powell (1996); Zadry & Yusof (2006); Brah <i>et al.</i> (2000); Yeung <i>et al.</i> (2006); Di Benedetto <i>et al.</i> (2008); Yeung, <i>et al.</i> (2006); Yusuf <i>et al.</i> (2007); Hendricks & Singhal (2001); Ravichandran (2007)

Appendix D. Result of exploratory factor analysis (EFA) for QM practices

	Component							
	1	2	3	4	5	6	7	8
MAL1	.815	.088	.147	.132	.136	.033	-.004	.087
MAL2	.713	.128	.167	.081	.226	.068	-.058	.115
MAL3	.841	.108	.103	.160	-.029	.028	.092	.087
MAL4	.804	.049	.041	.031	-.006	.136	.117	.043
MAL5	.761	.137	.133	.009	.188	.039	-.035	.123
MAL6	.601	.082	.160	.069	.237	-.072	.067	.385
TRA1	.159	.170	.178	.153	.102	.301	.107	.709
TRA2	.277	.134	.135	.088	.196	.312	.141	.720
TRA3	.271	.155	.142	.154	.242	.154	.228	.730
EMR1	.226	.090	.363	.138	.550	.176	.128	.222
EMR2	.114	.143	.211	.083	.717	.140	.189	.132
EMR3	.179	.114	.172	.146	.668	.315	.192	.194
EMR4	.241	.163	.138	.227	.755	.197	.128	.096
SQM1	.047	.159	.193	.756	.238	.042	.131	.176
SQM4	.020	.101	.208	.856	.187	.051	.019	.143
SQM5	.158	.147	.097	.784	.015	.168	.248	.053
SQM6	.268	.061	.092	.644	.044	.283	.193	-.012
CUR1	.160	.830	.069	.114	.131	.134	.106	.131
CUR2	.251	.772	-.071	.114	.099	.198	.054	-.060
CUR3	.136	.812	.213	.062	.105	.087	.022	.163
CUR4	-.008	.795	.136	.114	.061	.035	-.027	.125
QDR1	.149	.315	.283	.194	.209	.554	.271	.185
QDR2	.059	.144	.177	.156	.158	.742	.228	.207
QDR3	.049	.169	.286	.134	.288	.718	.080	.203
QDR4	.040	.143	.223	.215	.288	.646	.267	.293
PSD1	.233	.143	.707	.243	.181	.190	.218	.112
PSD2	.216	.097	.774	.231	.145	.202	.113	.093
PSD3	.199	.134	.714	.174	.189	.230	.258	.157
PSD4	.185	.107	.665	.082	.295	.167	.263	.167
PRM1	.040	.106	.266	.099	.202	.160	.744	.199
PRM3	-.020	.011	.221	.184	.107	.153	.789	.077
PRM4	.095	.006	.134	.309	.234	.236	.636	.137

Appendix E. Result of exploratory factor analysis (EFA) for Innovation

	Component				
	1	2	3	4	5
RPDI1	.095	.801	.077	.167	.061
RPDI2	.193	.904	.046	.050	.031
RPDI3	.079	.862	-.042	.141	.072
RPDI4	.197	.883	.049	.076	.140
RPDI5	.142	.874	.044	.070	.151
IPDI1	.860	-.009	.170	.140	-.003
IPDI2	.900	.164	.119	.103	.054
IPDI3	.870	.180	.113	.072	.091
IPDI4	.838	.187	.114	.066	.145
IPDI5	.839	.210	.118	.013	.123
RPCI1	.068	.132	.112	.878	.131
RPCI2	.071	.166	.142	.870	.139
RPCI3	.177	.124	.142	.803	.223
IPCI1	.183	.036	.881	.150	.109
IPCI2	.144	.014	.895	.069	.104
IPCI3	.182	.076	.837	.173	.135
ADMI1	.187	.110	.113	.153	.831
ADMI2	.053	.118	.099	.123	.848
ADMI3	.068	.119	.127	.188	.840

Appendix F. Result of Confirmatory Factor Analysis (CFA) for each construct

Construct	CFI	RMSEA	χ^2/df^*	NFI	NNFI
Management leadership	0.99	0.074	2.27	0.98	0.98
Training	1.00	0.000	0.00	1.00	1.00
Employee relations	0.99	0.077	2.45	0.99	0.98
Supplier quality management	1.00	0.000	0.02	1.00	1.00
Customer relations	1.00	0.000	0.28	1.00	1.00
Quality data and reporting	1.00	0.078	2.38	0.99	0.99
Product and service design	1.00	0.052	1.61	1.00	0.99
Process management	1.00	0.000	0.00	1.00	1.00
Radical product innovation	1.00	0.063	2.00	0.99	0.99
Incremental product innovation	1.00	0.069	2.21	0.99	0.99
Radical product innovation	1.00	0.000	0.00	1.00	1.00
Incremental process innovation	1.00	0.000	0.00	1.00	1.00
Administrative innovation	1.00	0.000	0.00	1.00	1.00

χ^2/df : Management leadership (20.39/9 = 2.27); Employee relations (4.90/2 = 2.45); Supplier quality management (0.02/1 = 0.02); Customer relations (0.28/1 = 0.28); Quality data and reporting (4.75/2 = 2.38); Product and service design (1.61/1 = 1.61); Radical product innovation (7.98/4 = 2.00); Incremental product innovation (8.85/4 = 2.21)

Appendix G. Measurement models of each construct

Appendix H. Second-order model for behavioural practices and mechanistic practices

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