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Relationship between quality management practices and innovation

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ABSTRACT

The purpose of this study is to examine the associations among different quality management (QM) practices and investigate which QM practices directly or indirectly relate to five types of innovation: radical product, radical process, incremental product, incremental process, and administrative innovation. We test the proposed framework and hypotheses using empirical data from ISO 9001 certified manufacturing and service firms. The results show that a set of QM practices through process management has a positive relationship with all of these five types of innovation. It was found that process management directly and positively relates to incremental, radical, and administrative innovation. Organizational capability to manage processes may play a vital role in identifying routines, establishing a learning base, and supporting innovative activities. The findings also reveal that the value of an individual QM practice is tied to other QM practices. Therefore, highlighting just one or a few QM practices or techniques may not result in creative problem solving and innovation.

1. Introduction

Over the last 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 in seizing new opportunities and protecting knowledge assets (Hurmelinna-Laukkanen et al., 2008; Teece, 2000). Specifically, innovation plays a key role in providing unique products and services by creating greater value than was previously recognized and establishing entry barriers (Lloréns Montes et al., 2005). The importance of innovation has motivated researchers to identify the various driving forces of innovation (Becheikh et al., 2006). Some researchers contend that quality management (QM) could be one of the prerequisites of innovation (Hoang et al., 2006; Perdomo-Ortiz et al., 2006). QM practices contribute to operational and financial performance, allowing a firm to achieve a competitive advantage (Lagrosen and Lagrosen, 2005; 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).

Since the early 2000s, researchers have conducted empirical studies on the relationship between QM and innovation. While previous studies have provided interesting insight into the role of QM practices in innovation, a few shortcomings in these studies emerge from the literature review. First of all, earlier studies failed to explain which QM practices are directly or indirectly associated with innovation. Most studies examined only the direct relationship between QM practices and innovation. Researchers have tended to identify whether the implementation of QM practices is positively related to innovation (e.g., Abrunhosa et al., 2008; Martinez-Costa and Martinez-Lorente, 2008; Hoang et al., 2006) or which QM practice is directly related to innovation (Moura et al., 2007; Prajogo and Sohal, 2004). Second, 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 et al., 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 lead to only product and process innovations? If not, what other types of innovation should be explored to clearly address an association between QM and innovation? These studies devoted only limited attention to examining various types of innovation. This narrow view of innovation may be a barrier that causes a misunderstanding of the contribution of QM to innovation. The multidimensional types of innovation need to be tested to correctly understand the real value of QM on innovation. Third, earlier studies on the relationship between QM and innovation have provided inconsistent findings (See Appendix A). Some found that QM practices are positively related to innovation (e.g., Perdomo-Ortiz et al.,

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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 et al., 2007; Prajogo and Sohal, 2004; Santos-Vijande and Álvarez-González, 2007).

This study explores the following two questions: What relationship exists among QM practices? Which QM practices are directly or indirectly related to innovation? We concentrate on the research questions by conducting an empirical study of manufacturing and service firms. The objective of this study is to empirically investigate the relationships among QM practices and to explore which QM practices are directly or indirectly associated with five types of innovation: radical product, radical process, incremental product, incremental process, and administrative. The remainder of this study is organized as follows. The following section describes the extant literature, gives a research model, and presents hypotheses. The next section presents methodology, including data collection, measurement scales, measurement analysis, and hypothesis testing. Finally, this study concludes with a discussion, notes the implications of the results, and gives suggestions for future research.

2. Theoretical background and hypotheses

This section discusses four topics: QM practices, classification of innovation, the relationship between QM and innovation, and a research model.

2.1. QM practices

QM is a holistic management philosophy that fosters all functions of an organization through continuing improvement and organizational change (Kaynak and Hartley, 2005). QM captures features from distinct organizational models and extends them by offering principles, methodologies, and techniques (Spencer, 1994). Researchers emphasize that it is necessary for firms to define and develop QM practices that can assist a multi-dimensional management philosophy. QM practices refer to critical activities that are expected to lead, directly or indirectly, to improved quality performance and competitive advantage (Flynn et al., 1995).

Much attention in the research has been devoted to developing measurement constructs of QM and examining the association between QM practices and performance. Saraph et al. (1989) provide the first attempt to explore the measurement of QM practices (Perdomo-Ortiz et al., 2006). Their motivation is fuelled by the lack of a systematic attempt to organize a set of QM practices and the need to develop measures of the overall QM efforts in the literature. Using a survey of 162 general managers and quality managers, they propose and test 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), in their survey of 716 respondents, argue that QM studies on theory development and measurement failed to yield conclusive evidence related to validity and reliability. They suggest seven key dimensions of QM and scales: top management support, quality information systems, process management, product design, workforce management, supplier involvement, and customer involvement. Although there is little agreement on the list of QM practices (Samson and Terziovski, 1999), the efforts to develop a set of QM practices provide a theoretical foundation to scientifically connect traditional QM philosophies with practical activities.

The existing empirical research on the relationship between QM practices and performance is characterized by examinations of the interdependent nature of QM practices. Researchers view an organization to be a system of interlocking processes. The research, called linkage-oriented research, mainly tests associations among QM practices (Sila and Ebrahimpour, 2005). The linkage-oriented research relies on sophisticated analysis techniques, such as structural equation modeling, path analysis, and partial least square method (e.g., Flynn et al., 1995; Ravichandran and Rai, 2000) because the research mainly includes a complex research model with many variables. Actually, researchers have provided mixed findings on the relationships among QM practices. We, however, find two common views in the literature. The first view is that the successful implementation of QM can be attributed to the strong support of a combination of a series of practices, not just a few practices separately (Ravichandran, 2007; Nair, 2006; Schendel, 1994; Douglas and Judge, 2001). The second view is that QM practices could lead to improved performance in areas such as quality, operations, innovation, and business results (Flynn et al., 1995; Ravichandran and Rai, 2000; Hoang et al., 2006; Kaynak, 2003). We regard these views as basic assumptions in this study.

2.2. Classification of innovation

Innovation refers to new applications of knowledge, ideas, methods, and skills that can generate unique capabilities and leverage an organization's competitiveness (Andersson et al., 2008; Daft, 1978). This definition reflects a broader view of innovation by covering both administrative and technological innovation. In a global market, firms should have the ability to identify new chances, and to reconfigure and shield technologies, competences, knowledge assets, and complementary assets to accomplish a sustainable, competitive advantage (Teece, 2000). It is necessary to understand a type of innovation and its different features, because a specific type of innovation requires an organization to demonstrate unique and sophisticated responses. Researchers have explored the classification of innovation in different ways. Although previous studies have proposed various classifications of innovation, we found that empirical studies on innovation have explored five types of innovation: incremental product, incremental process, radical product, radical process, and administrative (e.g., Salavou and Lioukas, 2003; Di Benedetto et al., 2008; Herrmann et al., 2007; Vermeulen, 2005; Chandy and Tellis, 1998). We argue that investigating the various types of innovation helps practitioners break down their overall strategies on innovation into a particular type of innovation area and efficiently allocate resources for a specific type of innovation. Thus, our study applies the five types of innovation to analyze correlations with QM practices. In order to distinguish the five types of innovation, we need to discuss the differences between administrative and technological innovation; incremental and radical innovation; and product and process innovation.

Innovation is first split into administrative and technological innovation. *Administrative innovation* refers to the application of new ideas to improve organizational structures and systems, and processes pertaining to the social structure of an organization (Weerawardena, 2003; Damanpour, 1987). In contrast, *technological innovation* is defined as the adoption of new technologies that are integrated into products or processes (Yonghong et al., 2005). Administrative innovation is often triggered by internal needs for structuring and coordination, while technological innovation mainly responds to environmental factors, such as uncertain market conditions or technical knowledge (Daft, 1978; Gaertner et al., 1984). Administrative innovation uses a top-down approach where upper level managers commit to relevant activities, whereas technological innovation applies a bottom-up approach where lower level technicians are involved (Daft, 1978). Administrative innovation requires considerable set-up costs and entails organizational disruption, influencing basic work activities directly and customers indirectly (Weerawardena, 2003). A specialized agency (e.g., a consulting firm) diffuses administrative innovation (Teece, 1980), while intellectual property laws (e.g., patents or trademarks) protect technological innovation (Hoffman and Hegarty, 1993). Depending on the degree and subject of innovation, technological innovation is further classified into incremental and radical innovation, and product and process innovation.

Technological innovation can be divided into *incremental* and *radical innovation* when considering the following features of innovation: the level of change (minor vs. major), a target customer or market (existing vs. new), and the level of risk (low vs. high). Incremental innovation refers to minor changes of existing technologies in terms of design, function, price, quantity, and features to meet the needs of existing customers (Garcia and Calantone, 2002; De Propris, 2002), while radical innovation is defined as the adoption of new technologies to create a demand not yet recognized by customers and markets (Jansen et al., 2006). Incremental innovation focuses on refining, broadening, enhancing, and exploiting current knowledge, skills, and technical trajectory (Gatignon et al., 2002), while radical innovation, regarded as competence-destroying (Teece et al., 1997), concentrates on market pull or technology push strategies (Li et al., 2008). Incremental innovation entails a low level of risk but provides fewer benefits (Koberg et al., 2003); by contrast, radical innovation requires great uncertainty and a high level of risk (Moguilnaia et al., 2005). A study found that radical innovation covers only 10% of all new innovation, whereas the proportion of incremental innovation is about 90% (Rothwell and Gardiner, 1988).

It is important for a firm to decide which subject should receive innovation for a new market position. The innovation subject is either a product or a process. *Product innovation* refers to changes at the end of providing products or services, while *process innovation* is defined as changes in the method of producing products or services (De Propris, 2002). When we consider both the degree and the subject of innovation, product innovation can be classified into radical product innovation and incremental product innovation (Reichstein and Salter, 2006; Huiban and Bouhsina, 1998). *Radical product innovation* is defined as innovation associated with the introduction of products (or services) that incorporate substantially different technology from that now in use for existing products, whereas *incremental product innovation* refers to innovation related to the introduction of products (or services) that provide new features, improvements, or benefits to existing technology in the existing market (Chandy and Tellis, 1998; Herrmann et al., 2007; 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 that improves the productivity and the efficiency of production activities (Garcia and Calantone, 2002; De Propris, 2002). Process innovation aims to introduce a new element in production materials, machinery, equipment, processes, task specifications, and workflow mechanisms (Damanpour, 1991). When reflecting both the degree and the subject of innovation, we classify process innovation into two types: radical process innovation and incremental process innovation (Reichstein and Salter, 2006). *Radical process innovation* refers to innovation associated with the application of new or significantly improved elements into an organization's production or service operations 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 with the purpose of achieving lower costs and/or higher product quality (Reichstein and Salter, 2006; Ettlie, 1983; Gatignon et al., 2002). Table 1 provides an overview of features and differences of the five types of innovation.

2.3. The relationship between QM and innovation

QM studies have empirically proved that a set of QM practices is positively linked to innovation (Feng et al., 2006; Hoang et al., 2006; Perdomo-Ortiz et al., 2006; Abrunhosa et al., 2008; Martinez-Costa and Martinez-Lorente; Prajogo and Hong, 2008). The empirical studies emphasize that QM practices can provide technicians or R&D workforces with opportunities for applying QM principles and techniques in their innovative activities where the opportunities enable them to efficiently detect customer demand, to actively generate knowledge sharing, and to continue improvement of working systems and processes. Thus, the adoption of QM in innovative activities helps an organization update changes in customer needs, minimize non-value activities, and reduce new product development time and costs. QM consequently generates customer satisfaction, innovation, and improved business performance. Many other researchers, however, argue that not all QM practices are directly related to performance or innovation (Flynn et al., 1995; Ravichandran and Rai, 2000). In other words, because a set of QM practices is interrelated there are relationships among QM practices. The relationships among QM practices have either a direct or indirect influence on performance. As Appendix B indicates, a QM practice, such as management leadership and training, indirectly contributes to performance through other QM practices. Therefore, in this section we discuss not only relationships among QM practices, but also linkages between QM practices and innovation.

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). Most empirical studies on QM provide a common view that management leadership is a starting point and significantly related to other QM practices (Sila and Ebrahimpour, 2005; Zu et al., 2008; Kaynak, 2003; Flynn et al., 1995; Anderson et al., 1995; Ravichandran and Rai, 2000; Ahire and Ravichandran, 2001). Management leadership is a minimum requirement to adopt and maintain other QM practices. Researchers, including Ahir and Ravichandran (2001), Ravichandran and Rai (2000), and Sila and Ebrahimpour (2005), assert that the commitment of top management creates a sophisticated QM infrastructure that is needed for improving other QM practices. Without strong top management support, it may be impossible to build an effective environment for QM and produce benefits from other QM practices. According to the empirical studies, management leadership is positively related to other QM practices, especially training, employee relations, supplier quality management, customer relations, and product design (Flynn et al., 1995; Kaynak, 2003). Top management establishes a learning-intensive environment for the adoption of QM because they ensure that adequate financial support is allocated for training and monitoring performance through training. The development of workforce skills and knowledge is required for understanding employee roles and achieving a better job. Top management, a workforce motivator, also plays an important role in communicating with, motivating, and empowering employees. Top management should trust employee performance, rather than trying to control employees (Besterfield et al., 2003). Distributing responsibilities and accountabilities enables employees to pay attention to organizational quality goals. Empirical studies found a positive relationship between management leadership and training, and employee relations (Anderson et al., 1995; Rungtusanatham et al., 1998; Ravichandran and Rai, 2000; Ahire and Ravichandran, 2001). This leads us to the following hypotheses:

Table 1
Comparison of radical, incremental, and administrative innovation.

Dimension	Technological innovation		Administrative innovation
	Radical innovation	Incremental innovation	
Objective	Create new customers and markets by introducing a previously unrecognized demand, replacing old technologies, or disrupting a current technology trajectory.	Meet needs of existing customers by refining, broadening, or combining a current technical trajectory, knowledge, and skills.	Increase the efficiency and the effectiveness of managerial systems and processes by obtaining new resources or adopting new programs.
Subject of innovation	Radical product innovation: products or services. Radical process innovation: processes.	Incremental product innovation: products or services. Incremental process innovation: processes.	Structures, policies, systems, and processes of management and organization.
Level of change	Major changes of technological directions, approaches, or linkages among core components.	Minor changes of existing components, design, price, function, quantity, or time.	Both major and minor changes.
Approach	Mainly a bottom-up approach initiated by lower level technicians and R&D workers.	Mainly a bottom-up approach conducted by lower level technicians and R&D workers.	Mainly a top-down approach initiated by upper level managers or administrators.
Level of risk	A high level of risk due to a high degree of complexity and technical/market uncertainties.	A low level of risk due to a greater level of certainty with known information.	Both high and low risks.
Output	Occur rarely but create entirely new product categories; identify unrecognized demands or methods; result in technological and marketing discontinuities; restructure marketplace economics.	Occur often and enrich the depth of technology innovation; improve certain dimensions of products or processes; expand brands and product categories; develop existing competencies.	Enhance organizational structures, administrative systems, and processes; add value for a firm directly or its customers indirectly.
Protection of output	Mainly protected by intellectual property law, such as patent; diffused under the technology transfer contract.	Mainly protected by intellectual property law, such as patent; diffused under the technology transfer contract.	Mainly not protected by intellectual property law; diffused by specialized agents (e.g., consulting firms).

H1. Management leadership will be positively associated with training.

H2. Management leadership will be positively associated with employee relations.

Top management establishes a long-term collaboration with suppliers. The role of suppliers is very important in obtaining high quality materials and leveraging unique knowledge and expertise (Lemke et al., 2003). The information exchange about innovative products and processes with suppliers enables a buying company to reduce product development time and cost and to focus on critical work. Top management emphasizes that high quality is the most important criterion in selecting a supplier. They understand that organizational competitiveness can be increased if an organization relies on high quality materials, not cost-based judgment. Further, improving customer satisfaction can be accomplished by the commitment of top management. When top management outlines quality goals for customer satisfaction, employees prioritize resources and their actions to contribute to this goal. Using quality based principles, top management can motivate employees to be involved in product design processes, develop teamwork, and enhance productivity. Researchers have empirically proven the positive relationship between management leadership and supplier quality management (Flynn et al., 1995; Ahire and Ravichandran, 2001; Kaynak, 2003), customer relations (Sila and Ebrahimpour, 2005; Flynn et al., 1995; Ahire and Ravichandran, 2001), and product design (Flynn et al., 1995; Kaynak, 2003). From this perspective, we suggest the following hypotheses:

H3. Management leadership will be positively associated with supplier quality management.

H4. Management leadership will be positively associated with customer relations.

H5. Management leadership will be positively associated with product/service design.

Training refers to the extent to which an organization provides employees with statistical training, job-related skill training, and quality-oriented training, such as quality techniques (Saraph et al., 1989). Empirical researchers, including Flynn et al. (1995), Ravichandran and Rai (2000), and Kaynak (2003), hold a common view that training is needed for developing employee participation in organizational QM efforts and enhancing their knowledge and skills on data collection and its use. Researchers have confirmed that training is a basic factor in the success of QM implementation. Unless employees know how to implement concepts or techniques of QM in their jobs, employees may resist and lack commitment to change, instead of giving a positive impetus or benefit. A well-trained employee tends to work efficiently and effectively to improve performance. Appropriate training offers opportunities for improving teamwork, reducing errors, and enhancing job satisfaction. In particular, training is directly related to the way employees work (Mehra et al., 2001). Employees recognize that they should build strong teamwork. When an organization adopts QM, employees should learn how to implement quality techniques and quality principles in their innovation work. Therefore, the following hypotheses are proposed:

H6. Training will be positively associated with quality data and reporting.

H7. Training will be positively associated with employee relations.

Employee relations refers to the extent to which employees are involved in quality efforts, participate in quality decisions, have responsibilities to provide quality, recognize superior quality performance, handle quality issues, and improve the general awareness about quality (Saraph et al., 1989). According to empirical studies – including Flynn et al. (1995), Kaynak (2003), and Ravichandran and Rai (2000) – employee involvement in quality efforts plays a key role in dealing with quality data, designing products, and managing processes. The success of QM implementation can be ensured if responsibility for quality is extended to all employees and all departments in an organization. Employees are the most important component in accomplishing success. An employee should understand how his or her job fits into the organizational goals and strategies to improve performance. Organizations should focus on encouraging employees to be involved in quality efforts and to be motivated and empowered. This is because 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 (Zu et al., 2008). The employee clearly understands the principle of continuing improvement. Further, an employee plays a crucial role in identifying, maintaining, and enhancing processes. An employee tries to implement quality improvement approaches, such as plan-do-check-act (PDCA). Using a team problem-solving approach and continuing improvement, employees can improve product/service design (Choi and Eboch, 1998; Zu et al., 2008; Evans and Lindsay, 2008). This leads us to the following hypotheses:

H8. Employee relations will be positively associated with quality data and reporting.

H9. Employee relations will be positively associated with product/service design.

H10. Employee relations will be positively associated with process management.

Supplier quality management refers to 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 et al., 1989). The development of a solid partnership with suppliers enables a buying company to exchange innovative ideas on new products and improve development processes incrementally. In other words, suppliers are seriously involved in the buyer's product design teams by offering key information about prospective components and detecting customer demand changes. This mutual association helps the buying company not only reduce time and cost in developing a new product, but also focus on its strategic technology development. Empirical studies have proven that if a company has a strategic partnership with suppliers, the company may generate a positive performance enhancement in product design and process management (Zu et al., 2008; Kaynak, 2003; Flynn et al., 1995). Therefore, the following hypotheses are proposed:

H11. Supplier quality management will be positively associated with product/service design.

H12. Supplier quality management will be positively associated with process management.

Customer relations refer to the extent to which an organization emphasizes understanding customer needs (Ahire and Ravichandran, 2001). A customer is one of the key decision makers in determining product specifications. A firm can understand and respond to changing demands by analyzing quality data and building a solid cooperation with customers. In other words, a close association with customers requires a firm to promptly update accurate information about customer demands, allowing the firm to reduce redesign cost and time, to deliver high quality products, and to satisfy customers. Existing empirical studies have proven that a close relationship with customers positively contributes to quality data (Mohrman et al., 1995; Forza and Flippini, 1998; Zu et al., 2008). This leads us to the following hypothesis:

H13. Customer relations will be positively associated with quality data and reporting.

Quality data and reporting refers to the extent to which an organization uses quality data, regularly measures quality, and evaluates employees based on quality performance (Saraph et al., 1989). Studies have empirically proved that managing quality data offers opportunities for establishing a strategic relationship with suppliers, designing a new product, and improving processes, all of which influence organizational performance (Kaynak, 2003). Organizations commonly use quality data when maintaining a partnership with suppliers (Samson and Terziovski, 1999). Employees, as process owners in their jobs, can use quality data when selecting a supplier, developing a specification, and assessing supplier performance. Further, in the product and service design stage, it is essential for organizations to implement quality data to develop customer-based products and prevent redesign. 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 other departments, such as marketing and R&D (Zu et al., 2008). Another benefit of quality data is to help employees when modifying and improving processes (Kaynak, 2003). Employees constantly update and share quality data with their colleagues. The management of quality data offers opportunities for identifying non-value-added processes and standardizing product development processes, allowing employees to focus on operating core processes. By relying on core processes, a firm is able to reduce development time and cost and to be more responsive to a competitive market. This leads us to the following hypotheses:

H14. Quality data and reporting will be positively associated with supplier quality management.

H15. Quality data and reporting will be positively associated with product and service design.

H16. Quality data and reporting will be positively associated with process management.

Empirical studies have showed that quality data can play a vital role in achieving innovation. Martinez-Costa and Martinez-Lorente (2008), in an empirical study of 451 firms, found that the use of QM tools leads to both product and process innovation. This infers that by implementing QM tools, a firm can identify potential innovation areas, develop innovation plans, and produce innovative products and processes. Miller (1995), in a survey of 45 large multinational firms, concluded that managing quality data is the most important QM practice 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. Therefore, the following hypotheses are proposed:

H17-1. Quality data and reporting will be positively associated with radical product innovation.

H17-2. Quality data and reporting will be positively associated with incremental product innovation.

H17-3. Quality data and reporting will be positively associated with radical process innovation.

H17-4. Quality data and reporting will be positively associated with incremental process innovation.

H17-5. Quality data and reporting will be positively associated with administrative innovation.

Product/service design is defined as the extent to which all departments in an organization are involved in design reviews, the extent to which an organization emphasizes productivity, the extent to which an organization makes specifications clear, and the extent to which an organization highlights quality (Saraph et al., 1989). Product/service design aims at increasing design quality and guaranteeing manufacturability design (Nair, 2006). 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. An efficient design 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 problems with quality, and to minimize failure rates (Zu et al., 2008). Empirical studies also indicate that product/service design can facilitate process management (e.g., Ahire and Dreyfus, 2000; Kaynak, 2003). This leads us to the following hypothesis:

H18. Product/service design will be positively associated with process management.

Process management may positively relate to incremental, radical, and administrative innovation. Process management is based on the notion that a firm's capability is embedded in processes and can be strengthened through effective management of processes (Das and Joshi, 2011). Managing processes encourage firms to develop best practices, called routines, that can be used to establish a learning base and support innovative activities (Perdomo-Ortiz et al., 2006). Process management involves two key activities: repeating routines and enhancing routines. The repetition of routines refers to organizational efforts to document processes, to measure process outcomes, and to repeat value-added processes (ISO, 2008; Klassen and Menor, 2007). As the firms repeat the critical processes, they have an opportunity to identify the best practices that could be applied to any type of innovation activities. A set of best practices, or routines, is a source of incremental learning (Benner and Tushman, 2002). Employees obtain knowledge and information through routines, while they measure and monitor outcomes of routines in a systematic manner. Routines are often applied to analyze root causes of a problem and prevent any possible error or defect (Ahire and Dreyfus, 2000). By repeating routines, firms can develop the stable, detailed, and analytical routines required to accomplish incremental process and product innovation in moderately dynamic markets (Eisenhardt and Martin, 2000).

Routine-based firms efficiently carry out innovation activities because they pay more attention to vital processes and avoid activities that do not add value (Hoang et al., 2006). Routines allow firms to find and adopt efficient processes and methods. These firms become more efficient in developing a new product from idea generation to commercial success, making them more attractive to investors. Efficient processes also allow some slack time that can be used to generate unique ideas and creative problem solving. Additionally, implementing routines reduces variation in quality and increases reliability in the outcome of a new product development project (Ravichandran and Rai, 2000). By using routines, firms can set up a shorter and more efficient development cycle, enabling them to innovate quickly and respond rapidly to customers (Nair, 2006). Routine-based firms can consistently produce faster and better products or services than competitors. Further, routines are of importance to firms struggling to innovate in their own organizational structures and processes (Perdomo-Ortiz et al., 2006). Routines include diverse procedures and skills that assist employees in improving their administrative systems or functions. Several empirical studies have shown that organizational routines lead to incremental learning and innovation (Hoang et al., 2006; Perdomo-Ortiz et al., 2006; Prajogo and Hong, 2008). Thus, we test the premise that firms have to repeat and improve routines to trigger administrative, incremental product, and incremental process innovation.

Enhancing routines, the second major activity, refers to a firm's long-term effort to tailor and continue to improve simple and flexible routines for radical innovation activities. Radical innovation may cause several outcomes, such as a high failure rate and uncertainty, a long-term development period, and costly investment. Stable and detailed routines may be limited to facilitate only incremental innovation activities. For radical innovation, routines should be simple, flexible, and highly experiential to allow for any unexpected adaptations in a high-velocity market (Eisenhardt and Martin, 2000). Obtaining simple and flexible routines is a prerequisite for reducing uncertainty and leveraging risk (Valle and Vázquez-Bustelo, 2009). Using routines, employees try to find new opportunities and improve processes that lead to a previously unrecognized demand. On the other hand, it is vital to guide radical innovation activities using formal routines, such as coordination and evaluation routines. Formal routines provide a crucial framework for guiding a radical innovation project in terms of budget and time. In various functions – such as R&D, marketing, and manufacturing – radical innovation projects often involve high risk and progress concurrently or in parallel (Moguilnaia et al., 2005). As a managerial guideline, routines play a significant role in completing a radical project on time and on budget. To maintain clear project goals and meet strict deadlines, managers use routines when evaluating and monitoring radical innovation projects. Using routines that include measures and evaluation criteria in each development stage, managers continue to assess project potential and sometimes terminate a poor project (Cooper, 1988). Written routines are shared among participants across long-term projects, reducing communication gaps and unnecessary activities. It is logical to assume that process management activities assist firms to establish a learning base and to continue to improve their innovation capability. Therefore, we test the following hypotheses:

H19-1. Process management will be positively associated with radical product innovation.

H19-2. Process management will be positively associated with incremental product innovation.

H19-3. Process management will be positively associated with radical process innovation.

H19-4. Process management will be positively associated with incremental process innovation.

H19-5. Process management will be positively associated with administrative innovation.

2.4. Research model

A proposed research model is shown in Fig. 1. Theoretical constructs and relationships among QM practices in the proposed research model are identified from a structural model developed by Kaynak (2003). Each relationship is double checked using the prior empirical findings presented in Appendix B. The proposed model is, however, different from the one of Kaynak (2003) in the following two ways. This study develops its own hypotheses associated with a dependent variable based on the innovation literature. Kaynak (2003) tested only the relationship between QM practices and metrics used for traditional performances: quality, inventory, and market performance. This study examines the link between QM practices and five different types of innovation and adds a hypothesis pertaining to a variable of QM practices: customer relations. Specifically, the proposed model examines a link between customer relations and quality data and reporting. The model by Kaynak (2003) did not encompass this link.

The model reflects a key philosophy of QM: the entire organization is a system of interlocking processes (Soltani et al., 2004).

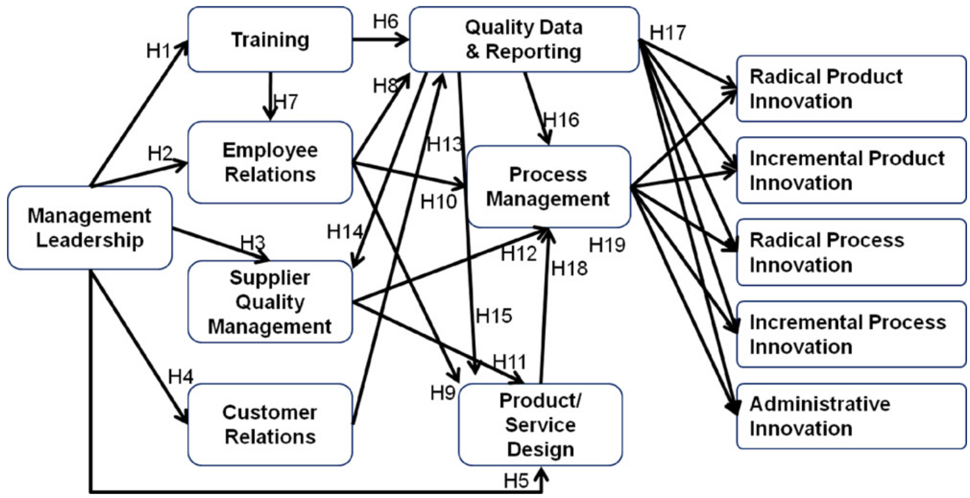

Fig. 1. Research model.

With respect to independent variables, this study utilizes a set of QM practices developed by Saraph et al. (1989). The set of QM practices proposed 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) and often examined as one of the solid sets 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 developed by Saraph et al. (1989). Unlike the original set of practices proposed by Saraph et al. (1989), the 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-oriented practice is broadly recognized as a representative QM practice in the real world (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 respect to dependent variables, this study examines five different types of innovation: radical product, radical process, incremental product, incremental process, and administrative. In earlier studies, the innovation construct is operationalized in terms of a single item (product or process) or two items (product and process), not these multiple types of innovation.

3. Methodology

3.1. Sample and data collection

A target sample of 2100 ISO 9001 certified manufacturing or service firms in Canada was selected. A stratified sampling technique was used to obtain data from firms of different sizes: large, medium, and small. The unit of analysis was 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). An organizational level study will add depth to the QM literature since there is a relative lack of studies investigating the contribution of QM practices at this level.

A questionnaire was mailed to 2100 firms. A total of 242 questionnaires were completed and returned. Of these, 19 were incomplete and they were excluded because of a large number of missing values in questions. One of the main reasons for this was that the questions were not applicable for some firms. The analysis, then, is based on a sample of 223 ISO 9001 certified manufacturing or service firms, and the response rate is 10.6%. The respondents were executives, middle-level managers, and professional staff. It was assumed that they were sufficiently well informed of the extent and role of QM practices in their firms to provide correct information. Similarly, previous studies reported that the commitment and knowledge of the executives and managers is extremely crucial when implementing QM (Burke, 1999). The sample consisted of 22 service firms (9.9%) and 201 manufacturing firms (90.1%). The manufacturing firms represented the following industries: 10 primary metal manufacturing (4.5%); 15 machinery manufacturing (6.7%); 15 transportation equipment manufacturing (6.7%); 13 chemical manufacturing (5.8%); 29 fabricated metal product manufacturing (13.0%); 18 computer and electronic product manufacturing (8.1%); 11 electrical equipment, appliance, and component manufacturing (4.9%); and other industries, such as construction and food packaging (40%).

To examine possible bias in self-report survey data, a non-response bias test and Harman'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 result of *t*-test between early and late respondents indicated no significant difference between the two groups. Additionally, we conducted *t*-test using the scores of two groups based on a demographic profile: firms with fewer than 50 employees (179; 80.3%) and firms with more than 50 employees (44; 19.7%). The *t*-test result on the different sized groups confirmed that no significant difference was found in the groups. This means that the data are free from non-response bias.

As this study relied on single respondents and perceptual scales to measure dependent and independent variables, we assessed the presence of common method variance (Scott and Bruce, 1994). Common method variance refers to variance caused by measurement methods, threatening the validity of empirical findings and misleading the interpretation of the results (Podsakoff et al., 2003). We performed a confirmatory factor analysis (CFA) to Harman's one-factor test to check whether common method bias exists. One factor, or a single factor, would account for most of the variance when common method bias is a serious threat to the research results (Podsakoff et al., 2003). It is assumed that common method variance is not a serious threat if the one-factor model has a poor fit with the data (Das and Joshi, 2011; Kim, 2009; Bou-Llusar et al., 2009). To develop the one-factor model, we loaded all of the measurement items into a single factor. The CFA results indicated that the one-factor model did not fit the data ($\chi^2 = 5588.86$ and df = 1274; χ^2/df = 4.39; CFI = 0.83; RMSEA = 0.15; NFI = 0.79; and NNFI = 0.82). Thus, we concluded that common method variance is not a major concern in this study.

3.2. Measures

To design the measurement instrument, we used existing measurement items addressed in the literature. Most measurement items for QM practices were adapted from the work of Saraph et al. (1989) and Kaynak (2003). The variable of customer relations was measured by using measurement items proposed by Flynn et al. (1995) and Zu et al. (2008). Items for innovation were largely adapted from the innovation literature, such as Herrmann et al. (2007) and Valle and Vázquez-Bustelo (2009). In particular, this study evaluates innovation with multiple measurement items. This attempt is consistent with that of previous studies (e.g., Wan et al., 2005), which 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. These items reflect the extent to which new products differ substantially from other existing products, a firm 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 firm is known by customers for radical product innovations. A seven-point Likert type scale was used, where 1 is equal to strongly disagree and 7 is equal to strongly agree. The questionnaire items included in each construct are presented in Appendix C.

3.3. Measurement analysis

Structural equation modeling was used to test the measurement model and the proposed hypotheses. 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 were reliable, unidimensional, and valid. In the first stage, reliability was assessed to identify the degree to which measures are free from random measurement error (Kline, 2005). CFA, using LISREL, was performed to explore reliability. Based on the results of CFA, this study used two different methods: analyzing the squared multiple correlation (R^2) and examining the composite reliability and the average variance extracted (Carr and Pearson, 1999; Boyer and Hult, 2005b). 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). 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 (Hult et al., 2004). According to a rule of thumb, a composite reliability of more than 0.7 or an average variance extracted of more than 0.5 indicates acceptable reliability levels (Fornell and Larcker, 1981; Kim, 2009). 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.

In the second stage, we tested for unidimensionality. Unidimensionality refers to the extent to which the measures in a scale reflect one underlying construct (Venkatraman and Grant, 1986). Following Sila and Ebrahimpour (2005), unidimensionality of QM and innovation constructs was assessed using CFA. Prior to testing CFA, we checked factor loadings of each item by conducting an exploratory factor analysis. The test aimed at removing items that do not load on primary factors. According to the literature, a factor loading of more than 0.40 or 0.45 is considered to be the minimum cutoff (Nunnally, 1978; Bhuian et al., 2005; Kathuria, 2000; D'Souza and Williams, 2000; Terziovski et al., 1997; Samson and Terziovski, 1999). The examination of factor loadings indicated that factor loadings of all items ranged from 0.55 to 0.90. A total of 51 items were retained and used for CFA. Then CFA was run to assess 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 suggests 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 over-reject 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); and 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. 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). 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; χ^2/df = 316/147 = 2.15; NFI = 0.94; and NNFI = 0.96. Thus, it is concluded that all constructs are unidimensional.

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.

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 twice on the models of constructs. The χ^2 difference values ranged from 4.135 to 41.859. This result indicates that constructs exhibit strong discriminant validity.

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. 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). The analysis result shows that values of AVE are considered acceptable (see Appendix D). Thus, the analysis of measurement models demonstrates that measures used in this study are reliable, unidimensional, and valid.

3.4. Hypotheses testing

Fig. 2 shows the 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. A *t*-value greater than 1.65 is significant at the 90% significance level, a *t*-value greater than 1.96 is significant at the 95% significance level, and a *t*-value greater than 2.58 is significant at the 99% significance level (Kaynak, 2003).

Table 2 shows the analysis results of the structural model. Overall results indicate 17 hypotheses were supported at the 95% or 99% significance level. The goodness of fit indices show that the structural model fits the data: CFI = 0.98; RMSEA = 0.043; χ^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; between management leadership and employee relations; between management leadership and supplier quality management; between management leadership and customer relations; and between management leadership and product/service design. 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–H11, H13–H16, and H18. The result also showed that process management is a significant and direct predictor of five types of innovation, supporting H19. Process management is positively related to five types of innovation: radical product, incremental product, radical process, incremental process, and administrative. Further, it was found that the importance of process management varies with the type of innovation. The contribution 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). It was found that non-significant relationships between quality data/reporting and five types of innovation did not support H17. Supplier quality management was not significantly related to process management (β = 0.09; *t*-value = 1.63) and did not support H12.

To further explore the relationship between QM practices and innovation, indirect impacts were examined. Table 3 shows the total and the indirect impacts of QM practices on innovation. One of the important findings was that QM practices are significantly and indirectly related to innovation. In particular, there were significant and indirect links between all types of innovation and QM practices (management leadership, training, employee relations, quality data and reporting, and product/service design). Some QM practices (supplier quality management and customer relations) were partially and indirectly related to a few types of innovation, such as incremental or radical process innovation. Further, although there was no significant and direct relationship between quality data and reporting and innovation, quality data and reporting had a significant direct and indirect relationship with process management. It can be interpreted that through process management, quality data and reporting indirectly result in innovation. It is also noted that quality data and reporting is indirectly associated with innovation, although not directly related to innovation.

Additionally, we tested direct relationships between QM practices and innovation, which are not included in a set of hypotheses. 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; χ^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 (β = 0.41; *t*-value = 2.29), between management leadership and radical process innovation (β = 0.25; *t*-value = 2.03), between employee relations and incremental process innovation (β = 0.50; *t*-value = 2.71), and between management leadership and administrative innovation (β = 0.28; *t*-value = 2.57). Perhaps these results may be promising for further empirical research on the direct role of QM practices on innovation.

4. Discussion and implications

The findings of this study support the notion that organizational efforts to establish and improve QM practices relate positively to innovative products or processes in both an existing market and an emerging market. To be more specific, the analysis result indicates that 17 out of 19 hypotheses are supported. Overall, the hypotheses that are supported clearly show that QM practices through process management are directly or indirectly associated with innovation. The findings provide vital insights for academics and practitioners interested in the relationship between QM practices and innovation.

Organizational capability to manage processes is very beneficial to firms that are struggling to create radical and incremental innovations in a competitive market. This study confirms that process management activities positively and directly relate to incremental, radical, and administrative innovation. Thus, it appears that information and knowledge in a set of routines accumulated through process management help firms establish a learning base and facilitate innovative and creative activities. Stable and detailed routines may add to the value of a product or a service in an existing market, whereas simple and flexible routines are likely to be valuable to firms targeting an emerging market. It also seems that appropriate control for measuring performance and coordinating conflicts in critical processes is necessary for guiding and

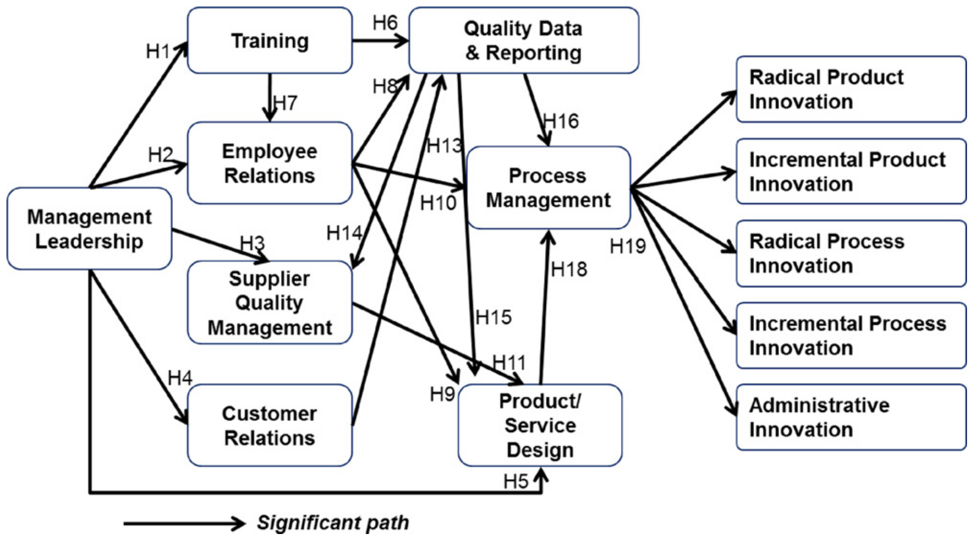

Fig. 2. Final structural model.

generating incremental and radical innovation. Control in process management is likely to assist firms to maintain stable goals, to reduce product development time, and to meet customer needs in both existing and emerging markets. This finding is consistent with the empirical evidence found by Khazanchi et al. (2007) showing that appropriate control, an innovation-supportive factor, enables employees to innovate within proper boundaries and concentrate on innovation initiatives.

Researchers also have pointed out that managing the process aids in facilitating creative problem solving and achieving innovation. Benner and Tushman (2002) stressed that process management activities increase incremental learning that enhances process efficiency and reduces variance in performance. In a longitudinal study, they reported that managing processes supports knowledge sharing and incremental innovation. Salomo et al. (2007), in an empirical study of 132 new product development projects, found that the proficiency of process management is a critical predictor of innovative performance in a new product development project. Using data from 108 technology service firms, Das and Joshi (2011) highlighted that firms should manage processes to encourage new ideas, creativity, and experimentation. They found that a firm's capacity for process improvement results in improving innovation capability and providing a competitive advantage.

One implication of these findings is that firms can benefit from identifying and enhancing organizational processes. Process management aids firms in fostering creative thinking, establishing a learning base, and triggering incremental and radical innovation. It means that process-oriented firms are likely to develop

Table 2
Analysis results of the structural model.

Path	Coefficient	*t*-value	Significance
H1. Management leadership → training	0.45	7.03	Significant***
H2. Management leadership → employee relations	0.14	2.37	Significant**
H3. Management leadership → supplier quality management	0.17	2.06	Significant**
H4. Management leadership → customer relations	0.43	5.54	Significant***
H5. Management leadership → product/service design	0.18	2.82	Significant***
H6. Training → quality data and reporting	0.38	3.81	Significant***
H7. Training → employee relations	0.56	6.60	Significant***
H8. Employee relations → quality data and reporting	0.59	5.18	Significant***
H9. Employee relations → product/service design	0.38	3.12	Significant***
H10. Employee relations → process management	0.23	2.22	Significant**
H11. Supplier quality management → product/service design	0.15	2.34	Significant**
H12. Supplier quality management → process management	0.09	1.63	Non-significant
H13. Customer relations → quality data and reporting	0.15	3.06	Significant***
H14. Quality data and reporting → supplier quality management	0.56	6.09	Significant***
H15. Quality data and reporting → product/service design	0.36	3.47	Significant***
H16. Quality data and reporting → process management	0.26	2.68	Significant***
H17-1. Quality data and reporting → radical product innovation	0.18	1.04	Non-significant
H17-2. Quality data and reporting → incremental product innovation	−0.23	−1.64	Non-significant
H17-3. Quality data and reporting → radical process innovation	−0.16	−0.92	Non-significant
H17-4. Quality data and reporting → incremental process innovation	−0.17	−1.16	Non-significant
H17-5. Quality data and reporting → administrative innovation	−0.07	−0.44	Non-significant
H18. Product/service design → process management	0.27	3.41	Significant***
H19-1. Process management → radical product innovation	0.41	1.97	Significant**
H19-2. Process management → incremental product innovation	0.86	4.95	Significant***
H19-3. Process management → radical process innovation	0.79	3.78	Significant***
H19-4. Process management → incremental process innovation	1.06	5.76	Significant***
H19-5. Process management → administrative innovation	0.81	4.38	Significant***

** $P < 005$: *t*-value is greater than 1.96.
*** $P < 001$: *t*-value is greater than 2.58.

Table 3
Total effects and indirect effects.

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

* $P<010$: t-value is greater than 1.65.
** $P<005$: t-value is greater than 1.96.
*** $P<001$: t-value is greater than 2.58.

organizational capability for innovation by applying various QM principles or techniques to engage in new ideas and creativity. Firms are unlikely to build competitive advantage in existing or emerging markets unless they invest their resources in process management activities. Process management involves important activities, such as identifying critical activities and repeating a set of routines. These activities provide firms with opportunities for generating incremental learning, increasing efficiency in a product development cycle, and responding quickly to customer needs. Similarly, managers involved in innovation projects should put more emphasis on employee ability to improve core processes and apply well-developed routines to innovation activities. Managers also need to be aware that stable and detailed routines generate incremental and administrative innovation, whereas simple and flexible routines enhance radical innovation (Eisenhardt and Martin, 2000). Depending on the target market, managers should use different routines and develop criteria to select or terminate an innovation project. Some short-term and cost-based routines regarding the project selection criteria may inhibit radical innovation activities (Benner and Tushman, 2002). Therefore, it is critical to understand the features and potential risks of radical innovation and develop long-term and value-based selection criteria.

Another important finding is that emphasizing just one or a few QM practices may not result in creative problem solving and innovative performance. Our data indicate that QM practices are interrelated with one another and influence innovation directly or indirectly. This means that the significance of an individual QM practice is strongly tied to other QM practices. QM practices seem to provide advantages to firms in terms of innovative performance only if a firm devotes attention to a set of QM practices, not just a few techniques or tools. For example, we found management leadership to indirectly and positively relate to innovation through other QM practices, such as training, employee relations, supplier quality management, customer relations, and product and service design. Similarly, supplier quality management is indirectly linked to innovation through product and service design. Process management not only positively and directly relates to radical and incremental innovation, but also mediates the influences of other practices, such as quality data and reporting, employee relations, supplier quality management, and product and service design.

Researchers have reached similar conclusions concerning the importance of adopting a set of QM practices. Kaynak (2003), in a study of 214 manufacturing and service companies, argued that the validation of the interdependence of QM practices should be emphasized to correctly understand the benefits of QM practices on performance. Ahire and Ravichandran (2001) conducted an empirical study of 407 plants in the automobile industry. From their study, Ahire and Ravichandran stressed that successful firms implement QM in an integrated fashion, not a cherry-picking manner. Using data from 130 R&D divisions of manufacturing firms, Prajogo and Hong (2008) found that QM practices are interrelated and facilitate innovative activities. Martinez-Costa and Martinez-Lorente (2008), in a study of 451 manufacturing and non-manufacturing firms, stressed that QM practices should be measured with a multidimensional scale instead of a one-dimensional scale, because the value of QM is based on a set of QM practices.

Another implication of these findings is that firms or managers should not put excessive emphasis on a single or a few QM practices and techniques. Our analysis highlights the interdependency of QM practices and the importance of a systematic approach for managing QM practices. Given that QM requires a holistic organizational effort, firms need to invest in the development of various QM practices that generate a creative synergy among individual practices. For managers and employees, a balanced and long-term view about QM efforts and performance is a critical skill that they have to possess. Firms that disregard a holistic perspective of QM and do not focus on synergies of QM practices may fail to yield innovative and financially rewarding performances. Thus, the overall improvement in a set of QM practices is fundamental to link organizational efforts to innovation and leverage investments in QM. These suggestions will be very useful guidance for a firm when investing its resources and changing its strategies to create innovation.

5. Conclusion and limitations

This study examines the relationship between QM practices and innovation. A proposed model comprises eight QM practices and five types of innovation. To test the proposed model, data were collected from a sample of ISO 9001 certified manufacturing or service firms. The analysis shows that QM practices are associated with innovation directly or indirectly and that the importance of individual QM practices is tied to other practices. In particular, the results indicate that process management directly and positively relates to all types of innovation.

Limitations of this study should be recognized, providing researchers with future research opportunities. First, respondents for this study are ISO 9001 certified firms. The firms fit the research purpose because they are familiar with terminologies and concepts of QM practices. However, other QM-intensive firms, 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 firms that have been awarded the MBNQA or the EFQA but are not ISO 9001 certified. Further, it may not be possible to generalize our findings for firms that are not ISO 9001 certified. Because our data involves only ISO 9001 firms, the findings of this study may not be applicable to non-certified firms that are likely to have less-developed quality programs. Future studies could be conducted to examine the relationship between QM practices and innovation in both ISO 9001 certified firms and firms that are not certified.

A second limitation is the use of cross-sectional data. Although the research is focused on examining the association between QM and 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. Third, while this study collected data based on respondents' perceptual judgment, considering their performance within a firm, there is little attempt to compare performance with other competitors in a similar industry. There is also no quantitative measurement item to evaluate innovation. Though this study adapts measurement items from the literature, future researchers need to develop more objective and comprehensive measurement items for extending this research. Fourth, it would be worthwhile to consider case studies to answer why and how QM practices lead to innovation. Using a straightforward survey analysis, we focused on investigating the relationship between QM practices and innovation. Our study could not clearly answer questions such as how and why QM practices result in innovation. Case studies may offer in-depth insight on how QM-driven firms create innovation efficiently and why process management is the most important among QM practices in supporting innovation activities.

Despite these limitations, this study contributes to the development of the literature in the following ways. The study enhances our understanding of which QM practices relate to each other and then, directly or indirectly, result in innovation. Earlier studies were limited to simply identifying a list of QM practices that directly influence innovation. Unlike the previous studies, this study investigates direct and indirect linkages among QM practices and clearly shows the positive relationships between QM practices and innovation. Furthermore, this study extends the boundaries of current studies by testing the relationship between QM practices and five different types of innovation, such as radical product and incremental process innovation. We also provide empirical evidence of the significance of process management that may assist firms or managers to identify routines, to establish a learning base, and to support innovation initiatives. It will be beneficial for practitioners to develop innovation strategies and to allocate resources effectively, as needed by the type of innovation.

Appendix A. Empirical studies on the relationship between QM practices and innovation.

Studies	Data sources	Analytical approaches	Independent 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 and analysis, people management, and process management. QM organic elements (2): leadership and strategic planning.	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.	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 et al. (2006)	252 firms: 194 from Australia and 58 from Singapore	Structural equation modeling	QM practices (6): leadership, strategic planning, customer focus, information and analysis, people management, and process management.	Process quality and product innovation (5): the number of innovations, the speed of innovations, the level of innovativeness (novelty or newness), latest technology used, and being the "first" in the market.	Behavioral practices (e.g., leadership and people management) are related to innovation.

Studies	Data sources	Analytical approaches	Independent variables	Dependent variables	Main findings
Hoang et al. (2006)	204 manufacturing and service firms in Vietnam	Structural equation modeling	QM practices (11): top management commitment, employee involvement, employee empowerment, education and training, teamwork, customer focus, process management, information and analysis system, strategic planning, open organization, and service culture	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 et al. (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.	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). 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.
Moura et al. (2007)	16 footwear manufacturing firms in Portugal	Correlation analysis	QM principles (5): autonomy, internal communication, consultation, formalization, and qualitative flexibility.	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).	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 and strategy, processes and resources, and partnership.	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 5 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 relationship between QM practices and administrative innovations. The effect of QM on innovation is moderated by market turbulence.

Studies	Data sources	Analytical approaches	Independent variables	Dependent variables	Main findings
Abrunhosa et al. (2008)	20 footwear manufacturing firms in Portugal	Multiple regression analysis	QM principles (5): autonomy, communication, consultation, qualitative flexibility, and supportive people management practices.	Process-based technological innovation (2): mean number of innovations adopted over time and mean time of adoption of innovations.	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.	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.
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 and analysis, people management, and process management.	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.

Appendix B. 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 et al. (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. Dependent variables (3): perceived quality market outcomes, percent of items that pass final inspection, and competitive advantage.	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 Workforce management → statistical control/feedback Supplier relationship → product design process Work attitudes → process flow management Work attitudes → statistical control/feedback 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 et al. (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 et al. (1998)	43 plants in Italy. 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 Continuous improvement → customer satisfaction	Learning → process management Process management → employee fulfillment Employee fulfillment → customer satisfaction

Studies	Data sources, QM practices, and dependent variables	Significant and direct relationships between QM practices	No significant and direct relationships between QM practices
Ravichandran and 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 and Ravichandran (2001)	407 plants in the 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 → employee management 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	Employee management → external cooperation 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	None

Studies	Data sources, QM practices, and dependent variables	Significant and direct relationships between QM practices	No significant and direct relationships between QM practices
		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	
Sila and Ebrahimpour (2005)	220 manufacturing firms in the United States.	Leadership → strategic planning	Strategic planning → human resource management
	QM Practices (7): leadership, strategic planning, customer focus, information and analysis, human resource management, process management, and supplier management.	Leadership → information and analysis	Strategic planning → business results
	Dependent variable (1): business results.	Leadership → human resource management	Customer focus → business results
		Leadership → process management	Information and analysis → process management
		Leadership → supplier management	Information and analysis → business results
		Leadership → business results	Human resource management → customer focus
		Strategic planning → customer focus	Human resource management → supplier management
		Information and analysis → strategic planning	Human resource management → business results
		Information and analysis → customer focus	Supplier management → process management
		Information and analysis → human resource management	Supplier management → business results
		Information and analysis → supplier management	
		Human resource management → process management	
		Process management → business results	
Zu et al. (2008)	226 manufacturing plants in the United States.	Top management support → customer relationship	Quality information → product/service design
	QM Practices (7): top management support, customer relationship, supplier relationship, workforce management, quality information, product/service design, and process management.	Top management support → supplier relationship	Quality information → process management
	Dependent variables (2): quality performance and business performance.	Top management support → workforce management	Product/service design → process 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	

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

Appendix C. Measurement items.

Management leadership: Adapted from Saraph et al. (1989), Kaynak (2003)
Our top management evaluates quality performance
Our department heads participate in the quality improvement process
Our top management has objectives for quality performance
Our top management has laid down a comprehensive goal-setting process for quality
Quality issues are reviewed in organizational top management meetings
Our top management considers quality improvement as a way to increase profits

Training: Adapted from Saraph et al. (1989), Kaynak (2003)
Our organization provides employees with specific work skills training
Our organization provides employees with quality-related training
Our organization provides managers and supervisors with quality-related training

Employee relations: Adapted from Saraph et al. (1989), Kaynak (2003)
Our organization provides employees with feedback on their quality performance
Hourly/non-supervisory employees participate in quality decisions
Building quality awareness among employees is ongoing
Employees recognize superior quality performance

Supplier quality management: Adapted from Saraph et al. (1989), Kaynak (2003)
Our organization maintains long-term relationships with suppliers
Our organization has reduced the number of suppliers since implementing quality management and/or JIT purchasing[a]
Our organization selects suppliers based on quality rather than price or delivery schedule in order to improve organizational performance[a]
Our organization evaluates suppliers according to quality, delivery performance, and price, in order to improve organizational performance
Our organization has a thorough supplier rating system
Our suppliers are involved in our product/service development process

Customer relations: Adapted from Flynn et al. (1995), Zu et al. (2008)
We frequently are in close contact with our customer
Our employees know our customers
Our customers give us feedback on quality and delivery performance
Our customers visit our office or workplace

Quality data and reporting: Adapted from Saraph et al. (1989), Kaynak (2003)
Quality data (for example, error rates, defect rates, scrap, and defects) is available in our organization
Such quality data is timely
Such quality data (for example, cost of quality, defects, errors, etc.) is used as a tool to manage quality
Quality procedures are available to ensure the reliability and improvement of data gathering

Product/service design: Adapted from Saraph et al. (1989), Kaynak (2003)
Our organization conducts a thorough review of new product/service design before the product/service is produced and marketed
Our departments fully participate in the product/service development process
The quality of new products/services is emphasized in relation to cost or schedule objectives
Productivity is considered during the product/service design process

Process management: Adapted from Saraph et al. (1989), Kaynak (2003)
Inspection, review, or checking of work is automated
We usually meet the production schedule everyday[a]
Our work processes are automated
Quality techniques are used in order to reduce variance in processes

Radical product innovation: Adapted from Chandy and Tellis (1998), Atuahene-Gima (2005), Subramaniam and Youndt (2005), Herrmann et al. (2007), Valle and Vázquez-Bustelo (2009)
Our new products differ substantially from our existing products
We introduce radical product innovations into the market more frequently than our competitors
Our percentage of radical product innovations in the product range is significantly higher compared to the competition
The percentage of total sales from radical product innovations is up substantially
We are well known by our customers for radical product innovations

Incremental product innovation: Adapted from Atuahene-Gima (2005), Subramaniam and Youndt (2005), Jansen et al. (2006), Herrmann et al. (2007), Valle and Vázquez-Bustelo (2009)
Our new products differ slightly from our existing products
We introduce incremental product innovations into the market more frequently than our competitors
Our percentage of incremental product innovations in the product range is significantly higher compared to the competition
The percentage of total sales from incremental product innovations is up substantially
We are well known by our customers for incremental product innovations

Radical process innovation: Adapted from Huergo and Jaumandreu (2004), Reichstein and Salter (2006), Martinez-Costa and Martinez-Lorente (2008), Valle and Vázquez-Bustelo (2009), Lau et al. (2010)
Our organization has introduced new or significantly improved machinery and equipment for producing products or services
Our organization has introduced new or significantly modified productive processes for producing products or services
Our organization has introduced new or significantly improved information technologies for producing products or services

Incremental process innovation: Adapted from Huergo and Jaumandreu (2004), Reichstein and Salter (2006), Jansen et al. (2006), Martinez-Costa and Martinez-Lorente (2008), Akgüna et al. (2009)
Our organization introduced minor or incrementally improved machinery and equipment for producing products or services
Our organization introduced minor or incrementally modified productive processes for producing products or services
Our organization introduced minor or incrementally improved information technologies for producing products or services

Administrative innovation: Adapted from Kimberly and Evanisko (1981), Hoffman and Hegarty (1993), Weerawardena (2003), Elenkov et al. (2005)
Our organization implemented new or improved existing computer-based administrative applications
Our organization implemented new or improved existing employee reward/training schemes
Our organization implemented new or improved existing structures such as project team or departmental structures, within or in-between existing structures
Our organization obtained new financing sources[a]

[a] Items were dropped in measurement analysis procedures.

Appendix D. Discriminant validity assessment.

Variables	1	2	3	4	5	6	7	8	9	10	11	12	13	α[a]	AVE[b]
(1) MAL	1.00[c]													0.889	0.584
(2) TRA	0.54	1.00												0.863	0.685
$\Delta\chi^2$	22.34														
(3) EMR	0.52	0.70	1.00											0.848	0.586
$\Delta\chi^2$	29.20	25.87													
(4) SQM	0.34	0.46	0.55	1.00										0.855	0.607
$\Delta\chi^2$	24.24	22.97	22.14												
(5) CUR	0.39	0.47	0.46	0.38	1.00									0.867	0.625
$\Delta\chi^2$	21.56	24.05	30.79	17.89											
(6) QDR	0.34	0.73	0.76	0.57	0.51	1.00								0.886	0.661
$\Delta\chi^2$	29.41	10.66	13.96	9.59	12.50										
(7) PSD	0.51	0.62	0.74	0.58	0.42	0.72	1.00							0.892	0.680
$\Delta\chi^2$	14.376	15.60	12.15	7.20	18.09	4.23									
(8) PRM	0.26	0.58	0.66	0.57	0.29	0.73	0.71	1.00						0.792	0.564
$\Delta\chi^2$	41.86	22.71	24.39	13.70	33.14	8.16	7.64								
(9) RPDI	0.20	0.32	0.25	0.21	0.17	0.34	0.37	0.26	1.00					0.932	0.739
$\Delta\chi^2$															
(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
$\Delta\chi^2$									4.14						
(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
$\Delta\chi^2$									7.24	14.54					
(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
$\Delta\chi^2$									24.34	11.83	9.74				
(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
$\Delta\chi^2$									11.41	15.66	5.65	15.70			

$\Delta\chi^2$: Chi-square difference between a constrained model (Correlation = 1) and an unconstrained model (Correlation = free). The critical value: $\Delta\chi^2$ (Δdf = 1) > 3.84 (Boyer and Hult, 2005a). *Labels*: MAL, management leadership; TRA, training; EMR, employee relations; SQM, supplier quality management; CUR, customer relations; QDR, quality data and 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.

[a] Cronbach's α.

[b] Average variance extracted (AVE).

[c] Correlation values.

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