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PRODUCT DEVELOPMENT PRACTICES AND PERFORMANCE INDICATORS IN SOME OF THE EGYPTIAN INDUSTRIAL COMPANIES

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ABSTRACT

The purpose of this study was to explore the product development practices in different environments. This study develops, measures, and tests a general model of the interrelationship among selected three constructs of the key product development practices and its impact on two constructs of performance indicators. Based on a sample of 227 manufacturing executives and managers were in IT, engineering, quality, product development, and product management functions from different industries in Egyptian companies. Two sets of hypotheses describing the predicted influence between key product development practices and performance indicators are proposed. The partial least squares (PLS) procedure was used to assess the measurement model and test the research hypotheses. The results indicate that there is many similarities between the key product development practices in different environments and these practices explain 47.1 percent of the variance in product innovation and internal product quality. Statistical analysis found four out of the six hypotheses tested with two exceptions that heavy-weight product development managers are negative and are not significantly associated with internal product quality and usage of information technology is negative and is not significantly associated with product innovation. The findings of this investigation contribute to be the first to investigate the relationship between these variables in some Egyptian industrial companies. These results also provide theoretical and empirical support for these relationships in the area of operation management.

Keywords heavy-weight product development managers, concurrent engineering practices, internal product quality

1. Introduction

Since the 1980s, the needs of the manufacturing processes became more complex, the rapid development of globalization and the technological ability to earn concurrent engineering a broad acceptance in industries (Lawson and Karandikar, 1994). Koufteros, Vonderembse, and Doll, (2001); Koufteros and Marcoulides, (2006) suggested that firms are building different structural relationships to help them cope with these changes. Concurrent engineering (CE) is a mechanism that can reduce uncertainty and improve an organization's capabilities through concurrent work-flows, product development teams, and early involvement of constituents. CE enables information to flow through the organization quickly and effectively thereby, it enables communicate, clarification, and enactment. CE practices are also purported to have significant effects on enhancing product innovation capabilities, and internal product quality (e.g., Black-burn et al, 1996; Souder et al, 1998; McDermott's, 1999).

Few frameworks have been introduced in order to understand the relationship between one of the key product development practices (i.e., heavy-weight product development managers, usage of information technology and concurrent engineering) impact and performance indicators as measured through product innovation and internal product quality. Juarez, Seguiti, Mengual, and Ferrandiz (2015) stated that the importance of using the concurrent engineering as a management philosophy in the field of industrial companies because of the production of these companies has become a matter of effective and efficient application of information technology and knowledge engineering in order to quickly meet dynamic changes in the market. Concurrent engineering is aimed to get the right product at the estimated time, by providing the right information, personnel, materials and equipment from the most appropriate sources, who and where needed performed and to achieve further improvements of the product design process with the intention of offering products that function according to customer needs (e.g., Bouchlaghem, and Anumba, 2003; Raudberget, 2010; Bhasi, and Madhu, 2010).

According to (Ismail, Mamat, Abdul-Razak, and Abd-Wahab, 2013), the importance of information technology has increased in today's organizations. Prior studies (e.g., Chan and Tsou, 2007; Julio, 2008) have suggested that information technology plays a critical role in a firm's ability through innovations in products, services and customers. Hence, using information technology provides a mean for production staff to create numerous opportunities to improve and evaluate the product design, innovating new products and services, and developing varieties of product prototypes (e.g., Vermeulen & Dankbaar, 2002). The usage of information technology plays a fundamental role for the adoption and implementation of the innovation activities that the firms need to improve significantly the innovation of new products. Frishammar and cohort (2005) usually the ideas that become innovations are implemented by initiatives of the information technology, which translates in a customer´s satisfaction (Peñalba, Guzmán, and de Mojica, 2015).

Many researchers suggested that top management support plays a key role in influencing the adoption of innovational activities in organizations, and involves a larger use of work teams (Jung, et al. 2003; Elenkov, et al., 2005; Hoang, et al., 2009; Makri and Scandura, 2010; Al-Refaie, et al., 2011; Denti, 2012; Kim, et al., 2012; Ryan and Tipu, 2013). Organizations can improve decentralized decision-making mechanisms; create a communication network within the organization through the application of information technology (Lee, et al., 1995; Camp, 2005; Li et al, 2006). Innovation is considered as one of the main sources for a company growth. Fast changes in customer demand imply that a competitive advantage of a company can be only temporary (Zakić, Jovanović, and Stamatović, 2008).

Previous literature on the heavyweight product manager has highlighted the importance of the formal and informal influence (Wheelwright and Clark, 1992; Schilling and Hill, 1998) on the cross-functional product development team. Clark and Fujimoto (1991) and Koufteros et al., (2001) investigate how heavyweight product managers are considered as critical aspects of effective product development. Millson, Raj and Wilemon, (1996) and Rauniar, Doll, Rawski., and Hong, (2008), investigated the role of heavyweight product manager in new product development. Koufteros et al., (2001) examined the effect of concurrent engineering practices on product innovation and quality. Koufteros et al, (2006) presented the first conceptual frame based on previous studies (e.g., Millson et al., 1996; Donnellon, 1993; Koufteros et al., 2001, 2002b, 2005) focusing primarily on understanding and describing how key product development practices (e.g., heavy-weight product development managers, and information technology use) impact product innovation and quality through concurrent engineering practices as a moderator variable under varying levels of cellular manufacturing. The relevant empirical research has not yet to produce satisfactory evidences on the nature of the relationship between these constructs.

The research pertaining to the relationships between the constructs of managerial leadership and internal product quality management practices and production innovation is still in its infancy, so it is imperative to assess the potential relationships between them (Schniederjans and Schniederjans, 2015).

Therefore, the exploration of the nature of relationship between the key product development practices and product innovation and quality continues to be an important issue that deserves further research attention. This study is designed to empirically investigate these relationships. The rest of the study is organized accordingly. A background on the research constructs is presented first, followed by the research model and hypotheses, research method, research results, discussion of the research findings, research limitations and future research, and conclusions.

2. Research Objectives

1-Explore whether the product development practices actually contribute equally in different environments on performance indicators as measured through product innovation and internal product quality (Donnellon, 1993; Millson et al., 1996; Koufteros et al., 2001, 2006).

2-Examine the direct relationships among the key product development practices and performance indicators in some of Egyptian industrial companies.

3. Research Importance

1-The lack of empirical studies that explore the key product development practices and its impact on performance indicators in different environment (Donnellon, 1993; Millson et al., 1996; Koufteros et al., 2001, 2006). So, there is a need to grow the empirical base of the literature on these practices and also highlights the importance of examining the direct relationships between these practices and performance indicators.

2-Although there has been interest in concurrent engineering and its impact on product innovation, but there is still some confusion about its associated with the field of product development remains uninvestigated (Juarez, Peydro, Mengual, and Ferrandiz, 2015). In addition, Minguela-Rata, (2011) stated that few studies have focused on the direct influence of concurrent engineering on increasing the product quality.

3-The importance of information technology on current business practices has long captured the attention of practitioners and academics. However, the relationship between the use of information technology, product innovation and internal product quality needs to be tested and experientially supported (Ismail et al, 2013).

4- There is a few empirical evidence regarding the direct relationship between the concept of heavy-weight product development managers and the concept of product innovation (Wheelwright and Clark, 1992; Koufteros et al, 2006; Rauniar et al., 2008; Lin, Wub, and Cheng, 2015; Daneshgar and Sindakis, 2015).

4. Research Problem

The objective of this study can be structured into two main research questions:

1-To what extent did key product development practices (heavy-weight product development managers, usage of information technology and concurrent engineering practices) influence product innovation?

1-1: To what extent did heavy-weight product development managers influence product innovation?

1-2: To what extent did usage of information technology influence product innovation?

1-3: To what extent did concurrent engineering practices influence product innovation?

2- To what extent did key product development practices (heavy-weight product development managers, usage of information technology and concurrent engineering practices) influence internal product quality?

2-1: To what extent did heavy-weight product development managers influence internal product quality?

2-2: To what extent did usage of information technology influence internal product quality?

2-3: To what extent did concurrent engineering practices influence internal product quality?

5. Theoretical Framework

5.1. Heavy-weight Product Development Managers (HPDMs)

According to (Lin et al, 2015), heavy-weight product development managers are powerful senior product development managers with substantial expertise and decision-making authority in order to direct product development firm team members efforts, to develop a shared vision, to ensure work integration, and to overtake traditional functional boundaries (e.g., Clark et al, 1991; Hong and Schniederjans, 2000). Rauniar et al. (2008) reported that according to Clark and Fujimoto (1990); Schilling and Hill, (1998); Koufteros et al. (2002), the key to product integrity is a leadership from heavyweight managers who is considered as a senior executive with substantial expertise and have primary influence over the people working on the development effort and supervise their work directly through key functional people on the core team. Based on (Kahn, Barczak, Nicholas, Ledwith., and Perks, 2012; Lotfi, Sahran, Mukhtar, Zadeh, 2013) a heavyweight managers are generally the chief engineers and thus are technical experts and they are both of the formal and informal authority and personal expertise to support and direct cross functional teams in a product development project in order to assign people, allocate resources, and direct the development. Koufteros et al. (2006) argued that Wheelwright and Clark (1992) designated the new product development teams into four types such as lightweight, heavyweight, functional structure and autonomous teams and found that a key dimension of these teams is the role of team leader who is directly responsible to senior management for all the work done by the product development team. Heavy-weight product development managers have a positive influence on new product development team with standardized regression estimate of 0.463 and statistically significant at $p<0.001$ (Rauniar et al.,2008).

Senior management was strongly committed to new products and product development, committed the necessary resources to achieve the firm's new product goals, closely involved in the new product spending decisions, and had a central role in the new product project review process (Cooper, and Kleinschmid, 2007). Empowered senior product development managers is the most critical success factor for NPD in order to provide the capability to be responsible for different tasks such as allocating sufficient qualified people, ensuring that everyone involved in NPD activities understands the requirements of the NPD processes, reviewing NPD principles and procedures on a regular basis, establishing a cross-functional team can facilitate the interdepartmental interfaces, and promoting staff in early involvement in NPD process (Chaochotechuang, 2016).

Vyas (2009), matched with Carmen et al. (2005) about considering independence of decision-making as a good predictor of successful innovation management by giving the product development managers both of the real authority and broad influence across their organization to practise their tasks. Koufteros, Rawski, and Rupak (2010), clarify that Clark et al (1991) is a pioneer of defining the concept of the heavyweight manager. Heavyweight product managers are managers with authority and a broad range of responsibility. They make sure there is clarity thought the full product development, often test the products themselves, have multiple teams working at different locations, have power in the organization, intervene in all aspects of every aspect of new product design, can help the team members acquire environmental information, exchange views, interpret the task environment, resolve cross-functional conflicts, and reach a mutual understanding of the product development tasks. Heavyweight product manager is typically a senior manager within the organization and has the expertise (Koufteros, Vonderembse, & Doll, 2001, 2002), direct engineering managers, identify the role of chief engineer, translate top management vision into tangible blueprints and coordinate the details and attempt to create harmony, are agents of integration (Daft & Lengel, 1986). According to (Lenfle and Baldwin, 2007) heavyweight manager committed to the project through its entirety; empowered to make key decisions; and had the status, experience and resources to exert influence on both team members and senior managers. Whilst Schniederjans et al (2015) stated that while some studies express the importance of managerial leadership as a basis for enhancing the value of quality management in innovation (e.g., Kim, Kumar, and Kumar (2012), there is limited development on this relationship, thus there is a need to highlight the importance of managerial role on improving innovation through quality management practices.

5.2. Usage of Information Technology

Kleis, Chwelos, Ramirez, and Cockburn (2011) stated that many scholars such as (Sudarsan et al. 2005; Bartholomew 2005; Thomke 2006; Gordon et al. 2008) confirm the importance of using information technology as a potential contributor to production innovation efforts in order to enable efficient design capabilities. IT-based digital methods of design, prototype, and test have been improved product innovations. Technology like computer based design applications help to digitize a new product's design, to make it available throughout the innovation production process, to allow team members to integrate their design efforts, to develop virtual prototypes and to help engineers to use digital prototypes for running computer simulations and testing component compatibility. They found that usage of information technology plays a positive and significant role in innovation production.

Bstieler and Hemmert, (2010), are consistent with previous studies such as (Katzenbach and Smith, 1993; Lee *et al.*, 2000; Smith *et al.*, 2005; Hoegl and Parboteeah, 2006; Chen *et al.*, 2008) which found that the more people involved in the team work the more difficult the interaction between them. In line with the results of these studies, Schniederjans et al, (2015) asserted that a product development project manager should try to form a team with a small number of skills people to simplify transmitting the information between the members who working in multifunctional teams. In addition, designing the products requires from the managerial leadership to find new ways to simplify the design of the products and to involve the employees from the earlier stages of developing the product to be aware of the strategies and the tools required to simplify the design.

Minguela-Rata, (2011) found that there is a significant and positive relationship between the use of multifunctional teams and product quality with correlation coefficient (r=0.426), but the involvement of team members from the earliest stages has no significant influence on the development process. However, this result is no matched with the results provided by (Fleischer and Liker, 1992; Ulrich et al., 1993) who found that the importance of the involvement of team members from the earliest stages that enable the engineers to help early detection of problems, and achieve improvements in the product quality. Karningsih et al, (2015) found that this result is in contrast to previous researches such as (Hauptman and Hirji, 1996, 1999; Minguela-Rata, 2002; 2006; Koufteros et al., 2001, 2002, 2006) which asserted that the involvement of team members from different departments from the earliest stages of the development process is an important dimension to measure the concurrent workflow of information. Khandani, (2005) and Baden-Fuller, and Haefliger, (2013) suggested that the professional designers of software products should develop early prototypes even for the individual components of the product in order to test, to refine the parts before moving too far down the product development path, to evaluate each design alternative against the stated criteria, and to gather much information as possible to determine the potential for its success or failure. Using computer models and changing the design of the prototypes can also yield valuable information to assist in the decision phase can be made more rapidly, decreasing costs and shortening the development time. Koufteros et al, (2001), and Alegre-Vidal, Lapiedra-Alcami, and ChivaGomez, (2004) supported the results that derived from (e.g., Barkan, 1992; Millson et al., 1996) who found that the frequent change of engineering orders in product design, in engineering design and in production volumes due to lack of information about manufacturing capabilities or customer expectations is considered the most cited reason for delaying the time required to develop a product at any manufacturing systems.

Using information technology provides firms quickly identify customer needs from customer profile analysis a means for their employees to create numerous opportunities to innovate new products and services to fit customer needs , to evaluate designs and to enable employees to develop product prototypes (e.g., Preissl, 1999; Vermeulen & Dankbaar, 2002; Demirhan et al., 2006; Chan and Tsou; 2007; Julio, 2008). The results suggested that there is a good relationship with (β=0.943, p=0.000<0.05) between information technology adoption and product innovation (Ismail et al, 2013).

Lin, Wub, and Cheng, (2015), suggested that product design team members need to use of information technology and computers to access relevant data that helps them for testing both of the product design attributes and the early identification of design flaws, shorten the time for developing prototypes, and reducing the need for time-consumed in engineering changes through sharing information among them (e.g., Clark et al, 1991). Using information technology requires less formalized and less centralized organizational structures that support their employees to work as a team and to create new products with reliable, durable and safety features (e.g., Chen, 2007). Peñalba et al. (2015) stated that Karadal and Saygin (2011) who found that the usage of the information technology have significant positive effects on the development of new products which allows firms to have a capability to gather data about their customers' needs, expectations, and levels of satisfaction and to generate new ideas that make better use of information to provide high levels of innovation of its products and services to their customers.

5.3. Concurrent Engineering Practices

Concurrent engineering is a management philosophy, it is a technique that can reduce uncertainty and improve the competitive capabilities of an organization. It is usually manifested through simultaneous streams work, product development teams and the early involvement of senior management. The results suggested that concurrent engineering practices have significant direct effects on product innovation and have significant indirect effects on quality (Juarez et al, 2015).

According to (Koufteros, Vonderembse, and Jayaram, 2005; Zhu, Zedtwitz, Assimakopoulos and Fernandes, 2016) CE is characterized by three main components. First, is the cross-functional team, second, is concurrent work-flows (or overlap), and third, is the early involvement of participants (Koufteros et al., 2001). Concurrent engineering offers opportunity for creating new products in short time with the highest quality in order to answer today's market demand according to management's role, team's development, and using the electronic data interchange (Karningsih, Anggrahini, Syafi'I, 2015). Lenfle et al (2007) argued that the participants involved in the early stages of designing the product be forced to propose solutions that were not yet fully approved and monitor the process to completion. There is a correlation between the effectiveness of interdepartmental communication from the beginning of the process and product quality.

There are three general areas covered by concurrent engineering. First: the dependence of the multifunctional teams in order to integrate the designs of a product and its manufacturing and support processes; second: using computer-aided design, engineering and manufacturing methods to support the integration of design through products and process models and databases; and third: using a variety of methods of analysis in order to optimize the design of a product and its manufacturing and support processes (Juarez et al, 2015). Edmondson and Nembhard (2009), reported that developing products requires the formation of working groups teams from cross-functional, consisting of individuals from different functional disciplines as a key moderators of NPD team performance in order to contribute their expertise to refine or innovate products. Based on some previous studies (Cooper and Kleinschmidt, 1994; Griffin, 1997; McDonough, 2000), firms use cross-functional teams for NPD between 70% and 97% of, and 33% use them 100% of the time. As mentioned by (Minguela-Rata, 2011) CE as a management approach refers to each activity in manufacturing a product is started with using the information from the early stage in order to reduce in development time, costs, and improve the quality of a product. Koufteros *et al*, (2001) suggested that one of the more useful forms of lateral communication in product development situations, where joint efforts across multiple functional departments are required, is the cross-functional team. Early involvement of many constituencies is essential for improvements in product innovation capabilities.

Kinkel and Som (2010), mentioned that many research studies such as (Clark and Fujimoto, 1989, 1991; Krishnan *et al.*, 1997; Loch and Terwiesch, 1998; Terwiesch and Loch, 1999; Gerwin and Barrowman, 2002; Minguela-Rata *et al.*, 2006) proved that CE has a positive impact on reducing the time needed to develop new product. According to Hammedi, van Riel, and Sasovova, (2011), many scholars for instance (Schmidt, Montoya-Weiss, and Massey, 2001; Menzel et al., 2007; Schmidt, Sarangee, and Montoya, 2009) confirm the importance of product development managers to communicate with group members in early stages of the new product process, and promote information processing and sharing between members. Product development group members are more likely to cluster ideas and reflect on the appropriateness of selection tools and methods during a evaluating several ideas for a certain broad project. The previous studies such as (Boehm 1988; Boehm and Bose 1994; Yoram and Paz 2008) emphasized on how companies employ a variety of different product development processes through using concurrent engineering to design new products in order to reduce development time, and create better products. In addition, how these companies induce their developers to combine between the detailed design and testing stages for iterating several designs of prototypes, and gaining fast feedback from early prototypes (Ungera and Eppingerb, 2011).

Lin et al (2015) confirm the work done by (Boynton et al., 1992) about the difficulties of achieving the integration of information systems and CDP project tasks, if not impossible, without a heavyweight product manager who has authority to make decisions that cut across functions. The results found that the indictor of managers has enough influence to make things happen in the construct of CE has no significant influence product development. It is inconsistent with the findings reported by Mintzberg (1973), and Koufteros et al. (2002). The effect of given real authority over personnel on developing new product appears to be the most potent in the construct of the heavyweight product development managers with standardized regression estimate of 0.81that is statistically significant at $p<0.001$, while the effect of having a final say in budget decisions appears to be the important factor (β= 0.62) as supported by Rauniar et al. (2008).

5.4. Product Innovation

Koufteros et al (2005) defined product innovation based on Blackburn (1991) and Clark et al, (1991) as the capability of organizations to introduce new products, to adapt with the rapidly technological change and to innovate quickly and continually in order to attain the need of customers and providing better products. The results found the capability of developing a number of new features has the highest factor loading with 0.91 and the capability of developing new product and features has the lowest factor loading with 0.67. Product innovation is a process that includes different aspects for instance, technical design, research and development, production, management and commercial activities associated with the firm's capabilities of developing new products according to customer needs (Tohidi et al, 2012). Product innovations are improvements of existing products and development and commercialization of new products. Cooperation between different functions that includes forming of teams of inter-crossed functions is considered as an important factor for a product innovation success (Zakić et al, 2008).

Valentina, Paolo, Zoran, Franco and Franc (2010); Basu, Biswas, Biswas and Sarkar (2013), stated that with an ever increasing customer demand, today industries are going under high pressure to lunch the product with both of the better manufacturability and shorter cycle time and to consider maintaining consistent product quality is only the half job done in today's industrial environment supported by depending on different specialist group members work as a team. Kleis et al. (2011) show that product innovation involves ideas and concepts of development in terms of new technologies, product development in terms of (design); and engineering in terms of prototyping, and manufacturing. Koufteroset al, (2001) found that firms that experience a high technological and product change in their environment are using more CE practices. In addition, results suggest that CE practices have significant direct effects on product innovation.

Ungera et al. (2011) stated that product life cycles, technological advancement, and changing customer needs rapidly force companies to develop new products frequently and more efficiently by describing and demonstrating a design method, have high quality standards, and use well-understood technologies for building prototypes early enough to garner the information necessary to substantively change design (e.g., Smith and Reinertsen 1992; MacCormack 2000, Levardy and Browning 2009). Senior managers should have broad influence across the organization toward a clear understanding of the company's capabilities, a deep understanding of how the product innovations goals tie into the broader organization strategy. Additionally, they took charge, developed a strong product innovation and technology strategy for the organization (Cooper and Edgett, 2010). Ismail et al (2013) found that there is a positive relationship between product innovation and information technology performance with correlation coefficient (r=0.401).

This result is in agreement with (Juarez et al, 2015) who stated that the relationship between the highly innovative products and the implementation of concurrent engineering approach is depending on the features of the product, the customer needs and the technological requirements. This result is consistent with Koufteros et al (2006), who found that there are statistically significant and positive effects of concurrent engineering to product innovation with ($r=0.22, p<0:01$).

Karningsih et al (2015) asserted that management's role, and the cross functional team have the least level of CE implementation compliance for creating new products in short time. Koufteros et al (2006) found that the use of computers may also be indirectly related to product innovation with ($\beta=0.26$, $p< 0:01$). The capability of the firm of developing a number of new features in its products is the most important factor in the construct of product innovations followed by the capability of developing a number of new products with factor loading (0.91; 0.87) respectively. This result is consistent with Kahn et al, (2012) and Cooper and Kleinschmidt (1995), who found that a high-quality of a process is considered the most important factor to identify the performance of a new product, followed by a clearly articulated new product strategy. In addition, understanding customer needs ultimately depends on an organization's capability for gathering and using the formal and informal information across NPD activities between functional areas to innovate successful products.

According to Peñalba et al. (2015), the results showed that a greater use of information technology in SMEs influences positively and significantly on product innovation with standardized coefficient = 0.301 and $p < 0.01$). Daneshgar et al (2015) reported that several studies (e.g., Cooper, 2003; Comican and O' Sullivan, 2004; Billah, 2012) identified several reasons behind the high rates of failure in developing new product. They found that firms concentrated on internal processes instead of focused on customers' needs; ineffective communication that transferred between the departments; in-effected cross functional teams; poor product definition; and low quality product.

5.5. Internal Product Quality

Zhu et al (2016) stated that most studies associate with the effect of CE on product quality is indecisive on whether a positive relationship exists between product quality and CE (Koufteroset al., 2002; Koufteros and Marcoulides, 2006; McDonough, 2000; Ragatz et al., 2002; Rusinko, 1997; Sethi, 2000; Tatikonda and Montoya-Weiss, 2001). Clark et al (1991) asserted that CE used not only to reduce product development cycle time but also to decrease product quality. McDonough (2000) found that the use of cross-functional teams significantly related to team performance, including developing high quality products. Tatikonda and Montoya-Weiss (2001) showed that process concurrency, formality, and adaptability have a positive effect on product quality. Millson and Wilemon (2008) reported that based upon the prior researches (e.g., Rusinko, 1997; Sethi, 2000; McDonough, 2000; Tatikonda and Montoya-Weiss, 2001; and Marcoulides, 2006) suggested that different terms for measuring product quality such as function, safety, reliability, durability and performance and stated that measuring internal product quality is not explicitly explored in any of the studies on NPD and product quality. New product performance is a part of senior management's personal performance objectives. The use of cross-functional teams helps, but does not have the dramatic impact on performance that managers had expected. Rather, the quality of the teams seems to make all the difference to the business unit's new product performance (Cooper et al, 2007).

Lotfi et al (2013) and Clarks et al. (1991) defined product quality as the composite of product characteristics of engineering and manufacture that determine the degree to which the product in use will meet the expectations of the customer. Furthermore, it is the fitness of information content or accuracy of information processing along a chain of productive resources that link customer needs, product concepts, product design, process design, product structure and product function. Lawson et al (1994) found that implementing CE can lead to some potential benefits such as less development time and time to market, fewer engineering changes, reduction of defect rate, rework and scrap, and higher quality.

Kinkel et al. (2010) found that few studies examined the influence of CE on the internal product quality such as (Souder *et al*., 1998; Kratzer *et al.*, 2004; Büchel, 2005; Berchicci and Tucci, 2010). Based on the internal product quality problems that derived from (Cordero, 1991; Dobers and Söderholm, 2009), Minguela-Rata, (2011) proposed three reasons behind them. The first may be due to the lack of integration of the functional areas involved in the execution of the process, the second may be due to the product developing managers who take the decisions without joint consultation in a previous stages and the third may be due to the extent of the interact between the team members. Based on (Kleis et al, 2011), using IT provides data that enables a firm to develop in-depth knowledge of its customers in order to create new innovations that better fit customer needs and to offer high performance of a firm's products to its customers (Mithas, Krishnan, and Fornell 2005a,2005b). As a result of advances in the fields of information technologies, Al-Qutaish (2009) sets some characteristics for evaluating the internal product quality during the software development product life cycle such as, functionality, reliability, usability, maintainability, changeability, and durability. In order to standardize the software product quality measurement process and activities and to identify the capability of the companies to offer products with high performance that meet customer needs.

However, Hajjat and Hajjat (2014) examined two characteristics to measure the intrinsic value of the product. The first is the reliability of the product which determined through designing the components of the product and the second is the durability which determined by the level of quality of supplies and materials within acceptable tolerance rates in order to provide customers with products and services that satisfy their needs. Koufteros et al (2005; 2006) found that the most important factor in the construct of product quality is the capability of the firm to offer reliable products that meet customer needs, while capability of offering products that function according to customer needs over a reasonable lifetime is the least important factor. According to the operational capabilities, more-innovative firms give higher marks to quality mainly for providing high performance products, and providing durable products (Alegre-Vidal, 2004). This finding contradicts with (Maylor, 1997) who found that the highest mean value of rated benefit from using CE in developing the products was that the product meets customer needs with 7.19, while the mean value of the increased product performance was the lowest with 3.55. This result is not matched with Zhu et al, (2016), who found that CE does not have a significant impact on product safety performance. Lin et al (2015) found that the heavy product development managers have statistically significant effects on the fitness of information system and computer utilization on the internal product quality, as well as a reduction in design changes, and cycle time with (b=0.53, t=6.83). Millson et al, (2008) supported that there is a positive relationship between the new product development knowledge and managerial decision making by articulating the activities performed during the early stages of the new product development process which are important to the attainment of a quality product.

6. Research hypotheses

On the basis of the previous discussion, the following are hypothesized:

H1: The three product development practices are positively associated with the product innovation

H1-1: Heavy-weight product development managers are positively associated with product innovation.

H1-2: Usage of information technology is positively associated with product innovation.

H1-3: Concurrent engineering practices are positively associated with product innovation.

H2: The three product development practices are positively associated with internal product quality

H2-1: Heavy-weight product development managers are positively associated with internal product quality.

H2-2: Usage of information technology is positively associated with internal product quality.

H2-3: Concurrent engineering practices are positively associated with internal product quality.

7. Sample

The data used for this empirical research was administrated to a total sample of 271 managers and directors of which 44 were ineligible resulting in a response rate of 16.7 percent because the roles and the policies applied in these companies preventing their employees to be involved in external research studies, and in other side the research instrument was inadequately completed. The sample was drawn from IT, engineering, quality, product development, and product management functions. This sample consists of Egyptian industrial companies from three different industries that developed and produced diverse product categories from fabricated metal products, and electronic-electrical equipment and components, and transportation equipment.

8. Measurement

The research instrument used was a structured questionnaire and the design of the instrument benefitted from extant literatures dealing with product development practices and both of the product innovation and internal product quality dimensions. The questions were adapted from the works of (Roberts, 1977; Maidique, 1980; Clark et al, 1991; Koufteros et al., 2001, 2006). A questionnaire consisted of 26 indicators in order to measure the five constructs. There were 18 indicators for three constructs that used to measure the independent variables. The first construct consisted of four indicators for heavy-weight product development managers, the second construct consisted of six indicators for usage information technology, and the third construct consisted of eight indicators for concurrent engineering. Based on Koufteros et al, (2001, 2006) a five-point Likert scale was used where 1= strongly disagree and 5= strongly agree. Thus, there were 8 indicators for two constructs that used to measure the dependent variables. The first construct consisted of three indicators for product innovation, and the second construct consisted of five indicators for internal product quality.

8.1. Measurement of variables

-Descriptive statistical measures according to skewness and kurtosis tests were used to describe data for items and scale scores. According to (Gliner, Morgan., and Leech, 2009) skewness and kurtosis values less than 1.5 for all scales are considered as sufficient normality for multivariate tests.

-Based on (Hair, Black, Babin, Anderson. and Tatham, 2006) factor loadings of indicators associated with each construct should be equal 0.55 or above to ensure adequate validity. PLS computes a composite reliability score (CR) to measure the internal consistency of the hypothesized indicators in a single construct as part of its integrated model analysis. It is considered to be less biased estimate of reliability than Cronbach's Alpha, the acceptable value of CR is 0.7 and above.

- To assess the discriminant validity, the average variance extracted (AVE) should be calculated by running a correlation of each variable with each other variable and then compared the square root of the AVE with construct correlation coefficients and other measures. The AVE square roots represented as the bold and underlined diagonal elements and the diagonal elements must be greater than the off-diagonal elements for the same row and column, not the AVE value itself (Domino and Domino, 2006).

-To test the hypothesized model, partial least squares (PLS) based structural equation modelling technique with AMOS II has been used to analyze the data in order to establish a path model to examine the relationship among the key product development practices and product innovation and internal product quality. PLS is used to estimate the path coefficients that indicate the strengths of the relationships between the dependent and independent variables.

-To demonstrate the meaningful predictive power of a PLS model, this technique can estimate the value of R-squared that indicates the amount of variance explained by the independent variables and can outline how well the model is performing. It should be closed to 0.20 (and ideally 0.30 or higher) to be substantial and significant standardized paths to present the predictive power of the model. The results will be presented for both of the R-squared and the path coefficients reported in Chin (1998).

9. Results

Table 1 depicts the results of the descriptive statistics for the measurement of the key product development practices as independent variables (factor 1, 2, and 3) and performance indicators in terms of product innovation and internal product quality as dependent variables (factor 4 and 5). Table 2 displays the loadings of the measurement item and composite scale reliability. Table 3 depicts the results of the discriminant validity through the square root of AVE. Table 4 outlines the summary of path coefficients and significance levels. The descriptive statistics data for items and scale scores including the mean value and standard deviation (SD) for the collected valid survey results are listed in Table 1. The results showed that, for all scales, skewness and kurtosis values were within acceptable limits (less than 1.5), indicating sufficient normality for multivariate tests.

Table1. Means and Standard Deviations for all the items of the five variables

Factor and Items	Mean	SD	N
Factor 1 : Heavy –weight Product Development Managers (HWPDM)			
Product development managers are given ‘‘real’’ authority over personnel (HWPDM1)	3.69	.730	227
Product development managers have enough influence to make things happen (HWPDM2)	3.53	.782	227
Product development managers have a final say in product design decisions (HWPDM3)	2.09	.521	227
Product development managers have broad influence across the organization (HWPDM4)	4.11	.690	227
Factor 2: Usage of Information Technology (UIT)			
We use computers to improve designs (UIT1)	3.81	.985	227
We use computers to evaluate designs (UIT2)	3.67	.941	227
We use computerized systems for product development (UIT3)	3.79	.852	227
Computers help us in making engineering changes (UIT4)	3.76	.840	227
We use computers to develop product prototypes (UIT5)	3.75	.808	227
We use computers to coordinate product development activities concurrent engineering (UIT6)	3.87	.969	227
Factor 3: Concurrent Engineering (CE)			
Product and process designs are developed concurrently by a group of employees from various disciplines (CE1)	3.39	1.051	227
Much of process design is done concurrently with product design (CE2)	3.27	1.013	227
Product development group members share information (CE3)	3.39	.981	227
Product development group members represent a variety of discipline (CE4)	3.75	1.070	227
Product development employees work as a team (CE5)	3.74	.830	227
Process engineers are involved from the early stages of product development (CE6)	3.61	.981	227
Manufacturing is involved from the early stages of product development (CE7)	4.48	.881	227
Various disciplines are involved in product development from the early stages (CE8)	3.95	.870	227
Factor 4: Product Innovation (PI)			
Our capability of developing new product and features is (PI1)	3.80	.644	227
Our capability of developing a number of ‘‘new’’ features is (P2)	4.01	.586	227
Our capability of developing a number of ‘‘new’’ products is (P3)	3.71	.772	227
Factor 5: Internal Product Quality (IPQ)			
Our capability of offering products that function according to customer needs over a reasonable life time is (IPQ1)	4.21	.825	227
Our capability of offering safe-to-use products that meet customer needs is (IPQ1)	4.13	.596	227
Our capability of offering reliable products that meet customer needs is (IPQ2)	4.04	.724	227
Our capability of offering durable products that meet customer needs is (IPQ3)	3.80	.640	227
Our capability of offering high performance products that meet customer needs is (IPQ4)	4.33	.694	227

9.1. Assessment of Measurement Properties

As per the PLS procedure suggested by Barclay *et al* (1999), this model (Figure 1) was tested for item reliability, internal consistency (as measured by composite reliability) and convergent validity to assess the measurement adequacy of the model. Hair et al. (2006) concluded that items loading below 0.5 are deemed to be unreliable, three of the 26 items (UIT4, UIT6, and IPQ2). The revised model with 23 observed variables were again tested using PLS and all item reliabilities exceeded the 0.5 reliability criteria. Table 2 shows factor loadings of indicators associated with each construct were labelled as "heavy–weight product development managers" (construct 1: HWPDM) which includes four indicators, "usage of information technology" (construct 2: UIT) which includes four indicators, and "concurrent engineering" (construct 3: CE) which includes eight indicators. Factor loadings of indicators associated with each construct were labelled as "product innovation" (construct4: PI) which includes three indicators and "internal product quality" (construct 5: IPQ) which includes four indicators.

The results found that such values of composite scale reliability are shown to be larger than 0.7, so high levels of internal consistency reliability have been demonstrated among all the five constructs.

Table 2: Loadings of the Measurement Items and Composite scale reliability.

Construct and Items	Factor Loadings	Composite scale reliability
Heavy –weight Product Development Managers (HWPDM)		.862
(HWPDM1)	.823	
(HWPDM2)	.752	
(HWPDM3)	.839	
(HWPDM4)	.809	
Usage of Information Technology (UIT)		.840
(UIT1)	.760	
(UIT2)	.683	
(UIT3)	.858	
(UIT4)	.294	
(UIT5)	.836	
(UIT6)	.365	
Concurrent Engineering (CE)		.871
(CE1)	.729	
(CE2)	.760	
(CE3)	.820	
(CE4)	.846	
(CE5)	.759	
(CE6)	.803	
(CE7)	.829	
(CE8)	.779	
Product Innovation (PI)		.833
(PI1)	.798	
(P2)	.732	
(P3)	.837	
Internal Product Quality (IPQ)		.827
(IPQ1)	.745	
(IPQ1)	.742	
(IPQ2)	.405	
(IPQ3)	814.	
(IPQ4)	.752	

Based on the results presented in Table 3 the square root of the AVEs is shown in the main diagonal. The off-diagonal elements represent the correlations among the latent factors. The square root of the AVEs is greater than the correlations among the latent factors. Table 3 indicates that the discriminant validity of the latent factors was met, which means that all the latent factors are different from each other.

Table 3: Discriminant Validity through the Square Root of AVE (on diagonal)

	Heavy-weight product development managers	usage of Information technology	Concurrent engineering	Product innovation	Internal product quality
Heavy-weight product development managers	**0.650**				
Usage of information technology	0.201	**0.780**			
Concurrent engineering	0.337	0.410	**0.800**		
Product innovation	0.352	0.392	0.306	**0.580**	
Internal product quality	0.348	0.316	0.422	0.411	**0.807**

Note: The shaded and bold elements in the main diagonal are the square roots of AVE should exceed the inter-construct correlations for adequate discriminant validity.

9.2. Hypotheses testing

After assessing the measurement properties of the model, the revised model was tested again using PLS based on AMOS structural modeling method to test the hypotheses. The results of AMOS path analyses are discussed below in table 4 and Figure 1 outlines the final model, and highlights the results of hypothesis testing.

Regarding to H1-1, that tests the relationship between heavy-weight product development managers and product innovation. The result shows a positive and significant influence on product innovation with beta coefficient of 0.622 (t=7.432). This result confirms that heavy-weight product development managers allow easy improving a firm’s ability to adapt changes in product innovation. Therefore, this hypothesis is strongly supported.

Hypothesis 1-2 tests the relationship between usage of information technology and product innovation. The data yielded a positive but not significant beta coefficient of 0.027 (t=0.451). Therefore, this hypothesis is not accepted. This implies that usage of information technology does not influence on product innovation.

Hypothesis 1-3 tests the relationship between concurrent engineering practices and product innovation. The results show a positive and significant beta coefficient of 0.681(t=7.546). Therefore, this hypothesis is accepted.

Hypothesis 2-1 tests the relationship between heavy-weight product development managers and internal product quality. The results show a negative and not significant beta coefficient of -0.071 (t=1.243). Therefore, this hypothesis is not accepted. This implies that heavy-weight product development managers do not influence on internal product quality.

Hypothesis 2-2 tests the relationship between usage of information technology and internal product quality. The results show a positive and significant beta coefficient of 0.356 (t=5.939). Therefore, this hypothesis is accepted.

Hypothesis 2-3 tests the relationship between concurrent engineering practices and internal product quality. The results show a positive and significant beta coefficient of 0.210 (t=2.491). Therefore, this hypothesis is accepted.

The findings showed that the good of fitness of the overall model revealed that the R^2 value of the model is (47.1%) which refers to the predictive power of the model is relatively high in explaining (47.1%) of the variance in the product innovation and internal product quality variables. The model is statistically significant either, as the P-value for the model is (0.000).

Table 4 : Summary of Path Coefficients and Significance Levels

Hypotheses and corresponding paths	Expected sign	Standardized path coefficient	*t*-value	Significance
H1-1: HWPDM → PI	+	0.622	7.432	Significant
H1-2: UIT → PI	+	0.027	0.451	Not significant
H1-3: CE → PI	+	0.681	7.546	Significant
H2-1: HWPDM → IPQ	+	-0.071	1.243	Not significant
H2-2: UIT → IPQ	+	0.356	5.939	Significant
H2-3: CE → IPQ	+	0.210	2.491	Significant

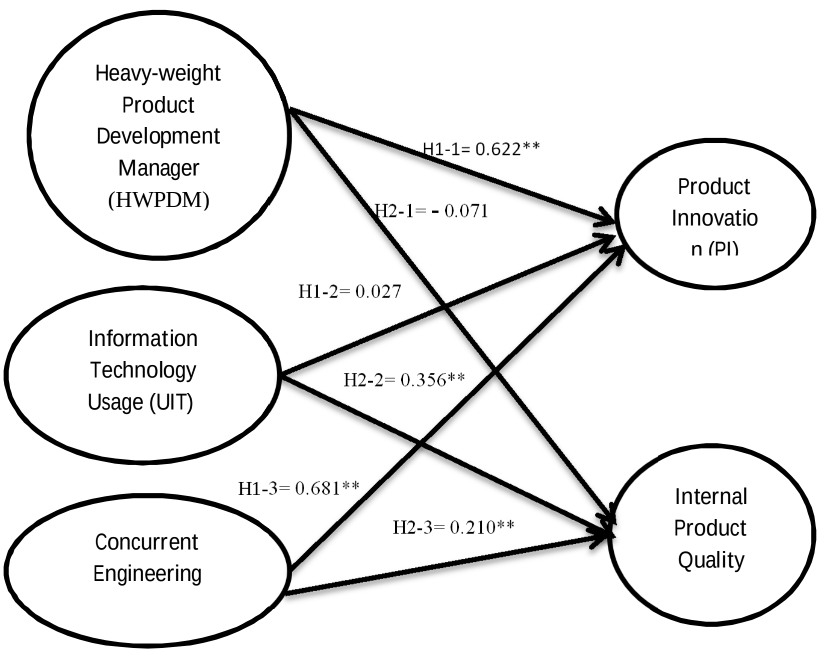

Figure 1: Model relationships among latent variables

10. Discussion

The results of testing the hypotheses suggest the acceptance of four hypotheses out of six regarding to the proposed relationships between key product development practices and performance indicators in terms of product innovation and internal product quality. Table 5 presents the difference between the hypotheses tested in the previous studies (Donnellon, 1993; Millson et al., 1996; Koufteros et al., 2001, 2006) and tested in the current study in some of Egyptian industrial companies.

Table 5: The difference between the hypotheses tested in the previous studies and some of Egyptian industrial companies.

Hypotheses and corresponding paths	previous studies (Donnellon, 1993; Millson et al., 1996; Koufteros et al., 2001, 2006)	Egyptian industrial companies
H1-1: HWPDM → PI	Accepted	Accepted
H1-2: UIT → PI	Accepted	Not Accepted
H1-3: CE → PI	Not Accepted	Accepted
H2-1: HWPDM → IPQ	Accepted	Not Accepted
H2-2: UIT → IPQ	Accepted	Accepted
H2-3: CE → IPQ	Not Accepted	Accepted

As expected, heavy-weight product development managers have a significant positive association with product innovation. This finding is largely in line with previous studies that supported this relationship (Koufteros et al., 2006; Rauniar et al., 2008; Lin et al, 2015; Karningsih et al., 2015) and also supported in the current study. This implies that the managers in the Egyptian companies play a critical role in product design decisions and have broad influence across the organization for improving the capabilities of their companies in order to innovate new products.

As expected, usage of information technology has a positive association with product innovation. It is apparent that the usage of information technology found no such significant association existed with product innovation in Egyptian companies. Moreover, this finding is consistent with (Mostafa, 2005) who stated that the lack of communication, groups conflicting goals, and rules and standard procedures were set for the employees to follow and keep them under control. These lead the Egyptian companies tend to be extremely formalized, bureaucratic and powerful influence on work team performance. Fear of failure of change was one of the main barriers blocking creativity and innovation in their working environment. In addition, the use of information technologies face major obstacles such as the cost of technology, uncertainty of benefits and the business impact, lack of knowledge, reliance on external consultants, the lack of reliability of systems and technological obsolescence (Peñalba et al., 2015). Egyptian companies should fully recognize the tremendous effect that can be brought by heavy product development managers specially, to enhance the internal product quality and should establish an organizational atmosphere that facilitates the extensive use of information technology by motivating their employees to use computerised systems that help them to improve the designs, to make engineering changes, to develop product prototypes, and to coordinate the product development activities. While, this finding rebuts the suggestions provided by the previous literature (Donnellon, 1993; Millson et al., 1996; Koufteros et al., 2001, 2006; Thomke (2006); Gordon et al. (2008); Ismail et al. (2013); Lin et al. (2015) which supported the direct significant association between the usage of information technology and product innovation to create new innovations that better fit customer needs and to increase the value of a firm's products to its customers.

As expected, concurrent engineering practices have a significant positive association with product innovation. This was consistent with previous studies such as (Lenfle et al., 2007; Rauniar et al., 2008; Kinkel et al., 2010; Juarez et al., 2015) and supported in the current study. The processes engineers in this study are emphasized on work as a team, shared information, and involved in product development from the early stages for creating new products in short time. This finding is inconsistent with (Donnellon, 1993; Millson et al., 1996; Koufteros et al., 2001, 2006; Karningsih et al., 2015) who suggested that cconcurrent engineering practices did not have a direct association with product innovation, it might indirectly effect on product innovation as internal product quality apparently mediates this relationship.

As expected, heavy-weight product development managers have a significant positive association with internal product quality. Surprisingly, not only was the relationship insignificant, the association was also negative. The findings pointed out that no such association between heavy-weight product development managers and internal product quality in Egyptian companies. This means that the present study did not produce any evidence to support this relationship. This lack of direct relation can be explained by that fact that the product development managers maybe did not have enough influence across their companies to take the final decisions to improve product quality performance (durability, safety, or reliability) or maybe they did not have a clear vision to link between their quality goals and customers' view of their companies' products. While, this finding is in line with the descriptive analyses of this item "product development managers have a final say in product design decisions" which had low to moderate mean values 2.09. However, this finding refutes the recommendation that heavy-weight product development managers should be used as a mechanism to ensure the internal product quality as proposed by (Millson et al, 2008; Lin et al, 2015) and may require the development of an appropriate companies' structure and culture to support the role of the product development managers through giving them power, authority, and status. However, some studies show a direct and positive association with internal product quality (Donnellon, 1993; Millson et al., 1996; Koufteros et al., 2001, 2006; Rauniar et al, 2008; Millson et al, 2008; Karningsih et al, 2015) which proved that there is indirect association between the heavy-weight product development managers and internal product quality through the moderator variable such as concurrent engineering.

As expected, information technology usage has a significant positive association with internal product quality. This finding was supported by most of the previous studies (Donnellon, 1993; Millson et al., 1996; Koufteros et al., 2001, 2006; Khandani, 2005; Al-Qutaish, 2009; Minguela-Rata, 2011); Baden-Fuller et al (2013); Lotfi et al (2013) and supported in the current study. This result empirically confirms the claim in the literature that top management in these companies reinforce the importance role of the product development activities to depend on computerized systems in designing, evaluating, developing prototypes and making engineering changes in order to meet their customers' needs.

As expected, concurrent engineering practices have a significant positive association with internal product quality. This result corroborates with most of the previous studies (e.g. Tatikonda and Montoya-Weiss, 2001; Kratzer *et al.*, 2004; Büchel, 2005; Berchicci and Tucci, 2010; Kinkel et al, 2010)) and supported in the current study. Nevertheless, this result was inconsistent with (Clark et al, 1991) who found that concurrent engineering practices used in incremental projects leads to decrease the product quality. In addition, the findings from the work of Minguela-Rata, (2011); and Zhu et al. (2016) also suggest that concurrent engineering practices did not have a significant impact on the performance of product quality. Donnellon, (1993); Millson et al., (1996); Koufteros et al., (2001; 2006) supported that cconcurrent engineering did exhibit indirect positive effect on internal product quality. With regard to product development practices, the results were not quite different between these types of environments. The impact of the three product development practices on both product innovation and internal product quality has been found to be fairly close in both environments, supporting the prevailing view in operational management literature. Differences in the results may be due to the use of different sets of data derived from different work environments or may be due to the type of the Egyptian functional structures and due to the political and economic conditions in which they are currently undergoing and which represent an obstacle to their ability to meet challenges in product development practices**.**

11. Conclusions

The motivation of this study was to explore whether the product development practices actually contribute equally on performance indicators in different environments. The results revealed that four out of six hypotheses showed positive and statistically significant relationships with performance indicators.

The findings suggest that this study confirms the existence of many similarities between the conceptual and prescriptive literature about the key product development practices in previous studies reported by (Donnellon, 1993); Millson et al., 1996); Koufteros et al., 2001; 2006) and their counterparts in some of Egyptian industrial companies.

The results of this study contribute the growing empirical base of literature on examining the direct relationships among the key product development practices in terms of (heavy-weight product development managers, usage of information technology, concurrent engineering), and performance indicators such as product innovation and internal product quality in some of Egyptian industrial companies.

Furthermore, findings suggest that in the Egyptian companies product innovation is most influenced by heavy-weight product development managers and concurrent engineering practices. This findings also provide insights for a unique relationship between the dimensions of the concurrent engineering practices and product innovation in the Egyptian companies and the extent of implement CE practices is also important factor, which leads to better internal quality product. Therefore, the findings suggest that the effect of concurrent engineering on to quality is more direct in the Egyptian companies.

Specifically, the findings point out that it is important to find out what contextual variables that may explain why certain relationships show up as being statistically significant in certain studies and do not show up as being statistically significant in others. Where the findings of the current study point out that no such association between heavy-weight product development managers and internal product quality in Egyptian companies, nevertheless this relations is proved in the literature review.

Another contribution of this study is comparing the difference between the key product development practices and performance indicators in the previous studies and some of Egyptian industrial companies which found that heavy-weight product development managers can be viewed negatively related to internal product quality in the Egyptian industrial companies and positively related to internal product quality in the literature review (Donnellon, 1993); Millson et al., 1996); Koufteros et al., 2001; 2006).

The findings suggest that the Egyptian companies should encourage their managers to support the importance of using the information technology to enhance the product innovation.

Limitations and suggestions for future research

1-The ability to generalize the findings is limited but it is only considered as a preliminary exploratory effort. A more comprehensive survey is needed to better understanding the relationships which were examined in the current research.

2-Further research is needed regarding the relationships between the product development practices and performance indicators in both private and public industrial sector and in different countries that attempt to cross-cultural investigations in order to develop and to validate the reliable measures.

3-This study only examined three product development practices. Nevertheless, it is essential to the further studies to pay more attention to investigate the impact of supplier integration, customer integration and the effectiveness of various leadership styles, such as transactional leadership, or transformational leadership that may contribute to improve their product quality and their capabilities to be more innovative.

4-The research focused on two performance indicators only in terms of product innovation and internal product quality, so further researches should be done on other indicators that help in improving the competitive edge and firm performance.

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