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## The effect of information technology adoption and design customisation on the success of new product development

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**Abstract:** The advancement of Internet technology and customisation capability has set off research into their impacts on all business operations including New Product Development (NPD). Despite the heavy investment in research and development, few studies have examined how Information Technology (IT) is adopted; how design customisation capability is built, and whether they reveal close associations with NPD success. This paper aims to investigate into these issues. Using the data from 172 sample high-tech manufacturers, the effects of IT adoption and design customisation on NPD success are investigated. The results support the idea that IT adoption and design customisation have positive impacts on NPD success. Discussions and managerial implications for practitioners are also provided.

**Keywords:** NPD; new product development; information technology adoption; design customisation; organisational learning; customer involvement; project success.

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## **1 Introduction**

In the internet era, Information Technology (IT) and the trend towards globalisation have changed the way of doing business. Business environment becomes keener and market dynamics is getting more unpredictable and fast changing. Central to competitive success in today's highly turbulent environment is the firm's capability to develop new products. New products are increasingly cited as the key to corporate success in the marketplace (Cooper et al., 2004). NPD today must provide customer with values by designing products that fit customers' needs and to gain higher customer satisfaction and corporate profits. Unfortunately, the literature reveals that most NPD projects are very likely to fail (McMath and Forbes, 1998), making "How to manage NPD?" and "How to secure NPD success?" two important issues to address.

The NPD is considered to be vital for a company's long-term survival (Cooper, 2001; Schilling and Hill, 1998) and complex process that takes time and resources. It needs coordination of cross-functional and cross-regional teams (Ozer, 2000). The process of NPD includes a set of activities that begins with the perception of a market opportunity and ends with the production, sales, and delivery of a product (Ulrich and Eppinger, 2000) where the earlier stage that focuses on evaluating prospects and eliminating bad bets, and a late stage that maximises the remaining candidates' market potential (Bonabeau et al., 2008). According to Nambisan (2003), the success of NPD may come from four dimensions: process management, project management, information and knowledge management, and collaboration and communication. These four dimensions concern with the process aspect of NPD and have a complex interplay with the NPD context. Therefore, any effective deployment of corporate resource should be examined along these dimensions, in addition to aligning with business strategies (Palmer and Markus, 2000). As IT is one of the major corporate resources and is known to affect the success of NPD (Brown and Eisenhardt, 1995; Chen, 2007), its adoption and deployment need to support the four dimensions as well as synchronising with the business strategies (Bunker et al., 2007). One of the prevailing business strategies is design customisation (Da Silveira et al., 2001). Firms need to possess customisation capability to design and provide unique tailor-made products for each individual customer. The mass customisation capability is critical to Original Equipment Manufacturing (OEM) and

Original Design Manufacturing (ODM) firms that provide backbone support for their brand-name buyers. This capability is known to affect the success of NPD process (Da Silveira et al., 2001). Therefore, IT adoption and design customisation are two vital factors affecting NPD process and, in turn, NPD success. A clear understanding of these two factors can help managers utilise and allocate resources for NPD and manage the NPD practices effectively.

In this paper, the effects of IT adoption and design customisation on NPD success are examined. Past models and cases discussing the relations of IT adoption, design customisation and NPD success will be reviewed. Antecedents of IT adoption and design customisation will also be scrutinised. The rest of the paper is organised as follows. In the next section, the relevant issues reported in the literature are reviewed and the research hypotheses are proposed. Research methodology is then discussed, followed by a section of analysis and results that reports the empirically testing of the hypotheses with survey data obtained from Taiwanese high-tech manufacturing firms. Finally, the conclusions and managerial implications are discussed and future research directions are provided.

## **2 Literatures and hypotheses**

### *2.1 NPD success*

The success of NPD is associated with understanding market needs, incorporating information from integrated design into NPD (Ettlie, 1997), and fostering knowledge creation and sharing (Lynn, 1998). Cooper (1996) posits that the success of NPD requires the input of people in different functional departments and the involvement of customers and business partners in the NPD process. Godener and Söderquist (2004) suggest that the key areas include ensuring relevance of product portfolios, determining corrective actions, supporting product launch decisions, enhancing staff motivation and facilitating well-balanced decision making. Furthermore, Brown and Eisenhardt (1995) describe three types of NPD success:

- rational plan
- communication web
- discipline problem solving.

In rational-plan type of research, success is achieved via superior product, attractive market and rational organisation; in communication-web type, success is through internal and external communication; in discipline-problem-solving type, success is a balancing act between relatively autonomous problem solving and an overarching product vision.

To measure NPD success, Gruner and Homburg (2000) adapt the work from previous studies (e.g., Griffin and Page, 1993; Olson et al., 1995; Garvin, 1984) and suggest four dimensions of success: new product quality, financial success, process quality and inexpensiveness of new product ownership. Griffin and Page (1993) compare the NPD performance measures used in over 75 published studies and identify five independent measures of NPD success that include measures of firm-, programme-, and product-level performance, measure of financial performance, and measure of customer acceptance. Some researchers further suggest that companies should use different criteria at different

NPD evaluation gates (Hart et al., 2003; Tzokas et al., 2004). While such criteria as technical feasibility, intuition, and market potential are important in the early-screening gates, a focus on product performance, quality and budget is necessary after the product has been developed. Similarly, Suomala (2004) combines product life cycle with NPD performance measurement and provides a feasible framework for constructing the success measures of NPD.

## 2.2 *IT adoption for NPD*

IT adoption has been broadly studied (e.g., Jeyaraj et al., 2006; Ciborra and Willcocks, 2006), which includes how to use IT in their NPD activities to improve speed to market, productivity, collaboration, communications, knowledge management, product quality and market performance among others (Ozer, 2000; Barczak et al., 2007). For example, Kotlarsky (2007) report that LeCroy Corporation adopted and reengineered a monolithic system into a component-based system and globally distributed work to gain competitive advantage in the software development practice.

In this study, we adapt Nambisan's (2003) four dimensions (i.e., process management, project management, information and knowledge management, and collaboration and communication) to operationalise the construct of IT adoption for NPD as

- process/project management
- knowledge management
- collaboration management.

Note that the first two dimensions are combined into one dimension because we regard project management as one form of process management. The description of these three dimensions is as follows.

*Process/project management:* Process/project management for IT adoption is one of the most basic and important tasks for an NPD project. Firms have started to adopt structured NPD process management to bring rigour and stability into their NPD activities (Nambisan, 2003). To support NPD project effort, IT systems such as workflow and project management systems should be used to integrate interorganisational processes and enable e-commerce solution (Basu and Kumar, 2002). An integration of the IT systems enables engineering teams to manage a project and related product information collaboratively and on a real-time basis in a dispersed product development organisation (Mesihovic et al., 2004). More and more of today's IT systems are designed not only to provide a virtual command centre with access to all information through a common interface, but also to integrate workflow with the firm's process management (McGrath and Iansiti, 1998).

*Knowledge management:* Knowledge management system refers to a class of information systems applied to managing organisational knowledge (Alavi and Leidner, 2001). It has been proposed as an effective tool to support knowledge sharing (Wasko and Faraj, 2000). Modern NPD projects create extensive amount of information and knowledge. Techniques and databases used to support information/knowledge sharing with multiple entities in a distributed innovation environment are now critical for NPD success (Baba and Nobeoka, 1998; Nambisan, 2003). The types of knowledge shared during

the NPD process include not only the organisational knowledge but also the customer knowledge (Joshi and Sharma, 2004; Su et al., 2007). Although IT is known to engender creativity in product design (Kappel and Rubenstein, 1999), relying on procedural and declarative memory types of knowledge stocks should be avoided because it may stifle creativity and diminish *new product's* short-term financial performance (Kyriakopoulos and de Ruyter, 2004). Instead, informal social networks such as the electronic network communication structure is encouraged to apply to improve the knowledge flows (Whelan, 2007).

*Collaboration management:* Collaboration is a process of teamwork among members from different functional or geographical areas (Nambisan, 2003). For example, collaborative design is the process of designing a product through concurrent cooperation among the engineers from different functional areas in a manufacturing company as well as those from suppliers and customers (Sprow, 1992). Today, most NPD projects are co-developing products across organisational, functional, cultural and geographic boundaries (Dahan and Hauser, 2001). Such collaborative NPD effort is known to improve operational capabilities development (Mao and Jarvenpaa, 2008) and new product performance (Noori and Lee, 2004). Using web-based applications can facilitate collaborative NPD efforts by providing with geographically dispersed project team members an effective media for communicating and disseminating knowledge (Boutellier et al., 1998; Hameri and Nihtilä, 1997; Hartley, 1998). One caveat is that the process of collaborative NPD is very complex (Noori and Lee, 2004) and involves contract management and patents protection issues (Håkanson, 1993).

Given the above-mentioned discussion, adopting IT for project/process management, knowledge management, and collaboration management during the NPD process will increase the likelihood of success. Hence, we propose hypothesis 1 as follows.

*H<sub>1</sub>: IT adoption for NPD has a positive effect on NPD success.*

### 2.3 *Design customisation*

The concept of customisation is not just merely to communicate with customers, but also to create suitable products and services for specific customers (Winer, 2001). Customisation has already become a competitive advantage of enterprises that are able to design and produce products and services to every customer via high elasticity and integration (Da Silveira et al., 2001). Tu et al. (2004) posit that mass customisation is a strategy that many firms are adopting to increase the demand for products that meet the needs of individual customers. Several scholars (e.g., Kay, 1993; Lampel and Mintzberg, 1996; Gilmore and Pine, 1997) discuss that customisation occurs at all kinds of point-of-delivery in the value chain, ranging from basic receiving products by customer himself/herself to complex customisation of product selling, designing, manufacturing, assembling, and transporting, etc.

An important method of design customisation is modularity. Modularity refers to an NPD strategy in which interfaces shared among components in a given product architecture are specified and standardised to allow for greater substitutability of components across product families (Mikkola and Gassmann, 2003). Mikkola (2003) also explores the role of modularity in product architecture designs and discuss how it impacts outsourcing decisions with respect to division of tasks in functional specification and

product engineering. In addition, the coding systems in group technology are frequently used in modular design. For example, Manzini et al. (2004) discuss the application of a modular semi-automatic approach based on cellular flexible facilities and group technology tools in designing and controlling a flexible and robust assembly system.

The NPD can benefit from application modularity in which the reusability of existing applications modules avoids reinventing the wheel and reduces NPD project effort. Time, risk, costs and efforts of application development and system integration can be greatly decreased. In this study, we operationalise design customisation with customisation delivery, modular design, and customisation requirements. On the basis of the aforementioned discussion, design customisation is more likely to bring success to NPD. Therefore, we hypothesise the following:

*H<sub>2</sub>: Design customisation has a positive effect on NPD success.*

#### *2.4 Antecedents of IT adoption and design customisation*

A number of papers have discussed the factors that influence IT adoption and design customisation. For example, Scott Morton (1995) develops an MIT90 framework to guide organisations through their IT adoptions. The framework identifies management processes, structure, strategy used and individual roles as the dimensions that affect and be affected by IT adoption. Fichman (2004) models the determinants of option values associated with IT platform adoption from four perspectives: technology strategy perspective (including technology readiness), organisational learning perspective, bandwagon perspective and adaptation perspective and discusses how IT platform adoption would be affected. Davis (1989) proposes a Technology Acceptance Model (TAM) to measure user attitude and behaviour intention for assessing systems quality. Two system characteristics: perceived ease of use and perceived usefulness are identified and discussed. Oh et al. (2003) integrate various views from TAM, planned behaviour theory and innovation diffusion model, and address how adoption of broadband access is affected by individual-level factors. Srinivasan et al. (2002) discuss factors that would influence technological opportunism of technology-sensing capability and technology-response capability. These factors include the firm's culture focus, top management's advocacy of new technologies, organisational culture and technological turbulence. Bell et al. (2002) argue that organisational learning is embedded in four schools of thought: economic, managerial, developmental and process. They discuss how the four schools are applied to the key areas of NPD and design customisation. Gruner and Homburg (2000) discuss the performance impact of the intensity of customer interaction in different stages of the NPD process and the characteristics of the involved customers. Cohen and Levinthal (1990) discuss the absorptive capacity of an organisation resulting from the cumulative learning activities of its individuals and the transfer of knowledge within the organisation. They also provide the implications of absorptive capacity for the analysis of related innovative activities such as the adoption and diffusion of innovations. Wu et al. (2003) propose a unified framework that captures the antecedents of e-business adoption, adoption intensity and performance outcomes wherein business-related antecedents include top management support, organisational learning, customer orientation, and competitor orientation.

As for the influence factors of design customisation, Pine et al. (1993) suggest to make mass customisation work by using technology, learning from failures and creating a

new vision. Calantone et al. (1995) develop a framework for performing NPD process and regard top managers as the ‘captains of the ships’. While it comes to the long-term success, the ‘captains’ must engage in product development activities including product flexibility and customisation. Pujari et al. (2004) investigate the impact of organisational antecedents on greening industrial product development that customises product design for environment issues. The antecedents include functional interface of environmental specialists with design and product managers, environmental product policy and top management support. Jeffrey et al. (2003) examine specifically how project management practices, including project manager styles and skills, and senior management support, would affect the product development process. Song and Adams (1993) suggest that customer participation is one way to achieve product differentiation in NPD and identifies specific areas of participation.

There are many other factors that influence IT adoption and design customisation. Table 1 summarises the factors from previous studies. For the purpose of this study, we classify these factors into four dimensions: IT behavioural belief (Davis, 1989; Oh et al., 2003; Scott Morton, 1995; Wixom and Todd, 2005), top management support (Calantone et al., 1995; Jeffrey et al., 2003; Pujari et al., 2004; Srinivasan et al., 2002; Wu et al., 2003), organisational learning (Bell et al., 2002; Cohen and Levinthal, 1990; Fichman, 2004; Pine et al., 1993; Wu et al., 2003; Ruy and Alliprandini, 2008) and customer involvement (Gruner and Homburg, 2000; Song and Adams, 1993). The discussion of these dimensions follows.

**Table 1** Summary of influence factors on IT adoption and product design customisation

<i>References</i>	<i>Influence factors/perspectives</i>	<i>Main issues</i>
<i>IT Behavioural belief</i>		
Davis (1989)	Perceived ease of use Perceived usefulness Attitude Behaviour intention	Technology acceptance
Scott Morton (1995)	Management processes Structure Strategy used Individual roles	IT adoption
Oh et al. (2003)	Technology Acceptance Model Planned behaviour theory Innovation diffusion model	Broadband access adoption
<i>Top management support</i>		
Calantone et al. (1995)	Top management support	Product development activities including product flexibility and customisation.
Srinivasan et al. (2002)	Top management’s advocacy of new technologies Organisational culture Technological turbulence	Technological opportunism (technology-sensing capability and technology-response capability)



**Table 1** Summary of influence factors on IT adoption and product design customisation (continued)

<i>References</i>	<i>Influence factors/perspectives</i>	<i>Main issues</i>
<i>Top management support</i>		
Jeffrey et al. (2003)	Project manager styles and skills, Senior management support	Product development process
Pujari et al. (2004)	Functional interface of specialists with design and product managers Environmental product policy Top management support	Product development including customisation
<i>Organisational learning</i>		
Cohen and Levinthal (1990)	Prior knowledge Individual and organisational learning	Absorptive capacity; innovation
Pine et al. (1993)	Building up the capability of using technology Learning from failures Creating a new vision	Mass customisation
Bell et al. (2002)	Organisational learning	Product development
Wu et al. (2003)	Top management support Organisational learning Customer orientation Competitor orientation	e-business adoption
Fichman (2004)	Technology strategy perspective (including technology readiness) Organisational learning perspective Bandwagon perspective Adaptation perspective	IT platform investment and adoption
<i>Customer involvement</i>		
Song and Adams (1993)	Customer involvement	Product differentiation
Gruner and Homburg (2000)	Customer involvement stages Customer characteristics	NPD success

### 2.5 *IT behavioural belief*

IT behavioural belief can be regarded as the employees' attitudes and intentions towards using IT. One of the most widely discussed models for IT behavioural belief is the TAM proposed by Davis (1989). In this paper, we follow the TAM and define the IT behavioural belief in two dimensions: perceived usefulness and perceived ease of use.

*Perceived usefulness*: Usefulness refers to "the degree to which a person believes that using a particular system would enhance his or her performance" (Davis, 1989). Several studies have demonstrated the positive impact of perceived usefulness on the adoption of IT (Tao and King, 1996; Venkatesh and Davis, 2000; Wixom and Todd, 2005).

It typically denotes an extrinsic motivation factor; that is, the activity is perceived to be an instrument to a desirable end. Employees who perceive IT applications as useful vehicles to achieve desired outcomes are more motivated to use IT innovatively.

*Perceived ease of use:* Ease of use refers to “the degree to which a person believes that using a particular system is free of effort” (Davis, 1989). While usefulness pertains to extrinsic motivation, ease of use involves an intrinsic motivation factor. By investigating customer attitudes towards innovations, many recent studies have demonstrated that the adoption of IT increases when people expect the use of a system to be user friendly (Hong et al., 2002; Venkatesh and Davis, 2000; Wixom and Todd, 2005).

When the IT behavioural belief is high, it is expected that the firm more likely would adopt IT applications for NPD. Thus, we hypothesise the following:

*H<sub>3</sub>: IT behavioural belief has a positive effect on IT adoption for NPD.*

## 2.6 *Top management support*

Top management support has been frequently named as one of the most important factors for business and system changes. Top management support of new technologies is exhibited through emphasising the importance of organisational responsiveness to new technologies (Srinivasan et al., 2002) and is the catalyst for mobilising the resources for internal corporate venturing (Burgelman, 1983) and NPD (Howell and Higgins, 1990). Specifically, top management has the power to reduce interdepartmental conflict and facilitate rapid business implementation by building an organisation-wide consensus related to strategic business options (Dess and Origer, 1987).

Recent writings in the NPD literatures suggest that certain ‘softer’ dimensions that define the behavioural environment of the firm (De Brentani and Kleinschmidt, 2004) can have important impacts on the outcomes of complex and risky endeavours. These include the firm’s management commitment and organisational culture. A number of studies have also reported that one of the primary causes of IT system failures is the lack of top management support (Ravichandran and Rai, 2000). Persuading employees to buy in a new IT system is much more complicated than merely buying and installing system hardware and software. The key to successful IT adoption is to secure top management support. Thus, Hypothesis 4 is proposed here.

*H<sub>4</sub>: Top management support has a positive effect on IT adoption for NPD.*

Similarly, design customisation is a process innovation. With the top management support, R&D staff can have clear direction on the NPD process and increase the level of design customisation and competitive advantage in the customer-driven market. Therefore, the following hypothesis is proposed.

*H<sub>5</sub>: Top management support has a positive effect on design customisation.*

## 2.7 *Organisational learning*

The organisation’s learning ability describes a firm’s ability to evaluate, adopt and exploit external knowledge, and to recognise the value of new information, assimilate it and apply it to commercial goals (Cohen and Levinthal, 1990). Senge (1990) believes that the rate at which an organisation learns may become the only sustainable source of

competitive advantage. Businesses with higher organisational learning abilities are more likely to successfully manage their transitions and work with their customers and suppliers (Wu et al., 2003). Ruy and Alliprandini (2008) highlight organisational learning as a key element in NPD process management because it can ensure its continuous improvement. They provide a framework to help promote and facilitate this learning on a regular basis. Hansen and Lovas (2004) suggest that companies need to focus on transfers of technological competence between NPD teams situated in a focal subsidiary and the other subsidiaries in a multinational firm. Scott (2000) also states that NPD is often a collaborative process and needs interorganisational learning to cope with the complexity of new products. Adams et al. (1998) identify the organisational barriers that impede learning and develop specific ideas of how NPD professionals can cope more effectively with these barriers. These studies tell us that the success of both new technology adoption and new business practice introduction depends on how organisation copes and learns; therefore, we hypothesise the following:

*H<sub>6</sub>: Organisational learning has a positive effect on IT adoption for NPD.*

Like IT adoption, design customisation capability also relies on the ability of organisational learning. Both better learning mechanism provided by a firm and positive learning attitudes of the employees would facilitate the formation of and strengthen design customisation capability. Thus, Hypothesis 7 is proposed as follows.

*H<sub>7</sub>: Organisational learning has a positive effect on design customisation.*

## *2.8 Customer involvement*

Previous research has shown consistently the pivotal role of customer involvement in NPD (e.g., Gemunden et al., 1996; Håkanson, 1993). Customers may involve in not only generating ideas for new product but also co-creating the products with firms, testing finished products and providing end user product support (Nambisan, 2002). A number of studies also suggest that having the customer closely involved during NPD can greatly increase the success rate of new products (e.g., Cooper, 1996; Methe et al., 1997; Ottum and Moore, 1997).

Nambisan (2002) suggests that customer involvement can enhance product concept effectiveness and Gupta and Souder (1998) address that customer's early participation is an important factor of NPD success. In other words, frequent customer contacts would be required to build up design customisation capability. Since the quality of a product is in the eyes of a customer, co-developing with customers would enable firms to understand the customer's needs for new products. Hence, we hypothesise the following:

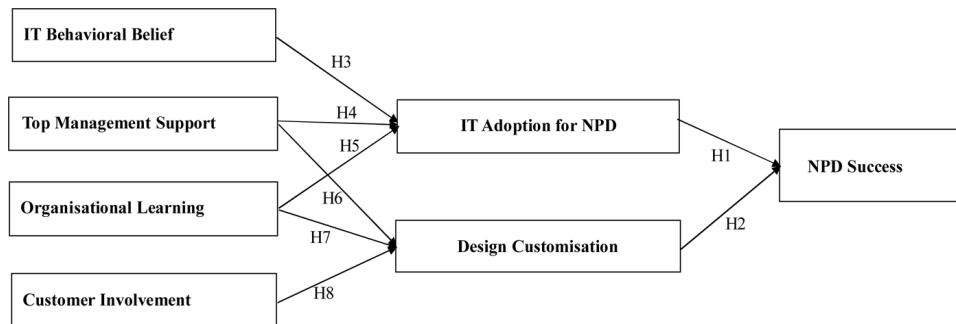
*H<sub>8</sub>: Customer involvement has a positive effect on design customisation.*

On the basis of the above-mentioned literature reviews and the discussion, we postulate IT adoption and design customisation be affected by the antecedents and in turn impact NPD success. Figure 1 indicates this causal model and the hypotheses that we postulated in this study. Moreover, there have been a number of researches (e.g., Zirger and Maidique, 1990; Moorman and Miner, 1997; Adams et al., 1998; Jeffrey et al., 2003) suggesting that most of our selected antecedents have direct and positive effects on NPD success. However, very few of the effects are strong. The reason might be that there are other mediating effects between IT capability and firm performance. That is, the

antecedents of NPD success are static in nature; there might be some mediators that are action-oriented and could bring NPD process to life. Therefore, we have identified IT adoption and design customisation as the potential mediators. The mediating effect is hypothesised as follows.

*H<sub>9</sub>: The effects of IT behavioural belief, top management support, organisational learning and customer involvement on NPD success are mediated by IT adoption for NPD and design customisation.*

**Figure 1** Research framework



### 3 Research methodology

#### 3.1 Samples

Data were collected by means of a survey questionnaire. The subjects were the R&D managers of Taiwanese high-tech manufacturing companies that were listed in the 2005 directory of top 5000 companies published by China Credit Information Service, Ltd. (<http://www.credit.com.tw/newweb/english/index.htm>). The directory record contains the company name, mailing address and telephone number of the representative. A total of 700 firms were randomly selected from the firms identified in the high-tech manufacturing sectors. Our survey required respondents to serve as key informants on a recent and typical NPD project in which they participated actively. The respondents were free in choosing the new product they reported on. For data collection, the questionnaire, along with a cover letter and a stamped return envelope, was sent to the R&D manager in each selected company. After the initial mailing, we received 125 responses and 11 returned mails indicating incorrect addresses or addressees. This reduces the total effective sample to 689. We carried out follow-up telephone calls for non-responses. Three weeks later we received 48 additional responses and increased the total responses to 173. Among the returned surveys, one was incomplete and therefore discarded. This reduces the sample size to 172, giving the effective response rate of 24.7%.

To examine the non-response bias, we tested the first-wave respondents against the second-wave respondents on observed variables as well as firm characteristics such as firm capital, number of employees and R&D spending ratio. No significant differences were found. This allows us to combine the two waves of samples into one for further analyses.

3.2 *Measures*

Scale development involved identifying the observed variables of each construct and establishing scale items to measure these variables. Both activities were predicated on our analyses of prior literature and field interviews (Churchill, 1979). Once the preliminary scales were developed, we submitted them to qualitative pre-test through interviews with 7 domain experts (5 practitioners and 2 scholars). These experts further proposed several refinements, modifications, and new items to enhance the validity of the scales. Table 2 exhibits the operational definitions and sources of the variables and their scale items. The questionnaire items for these scale items are listed in the Appendix. Most of these scale items were adapted from previous studies. All scale items of the observed variables were measured with a 5-point Likert scale, ranging from strongly disagree (1) to strongly agree (5). The questions of these scale items are listed in the Appendix. Table 3 shows the descriptive statistics of the individual variables. The score of each variable is measured by the composite average of its scale items.

**Table 2** Operational definitions of observed variables

<i>Variables</i>	<i>Operational definition and scale items</i>	<i>Sources</i>
IT behavioural belief	Perceived useful	Davis (1989), Hong et al. (2002), Oh et al. (2003), Tao and King (1996), Venkatesh and Davis (2000)
	Improving performance (Davis, 1989, Venkatesh and Davis, 2000)	
	Increasing productivity (Davis, 1989; Tao and King, 1996; Venkatesh and Davis, 2000)	
	Perceived ease of use	
Top management support	Easy to use (Davis, 1989; Hong et al., 2002, Venkatesh and Davis, 2000)	De Brentani and Kleinschmidt (2004), Howell and Higgins (1990), Ravichandran and Rai (2000), Srinivasan et al. (2002) and Wu et al. (2003)
	Easy to understand (Hong et al., 2002; Oh et al., 2003)	
	Top management awareness	
	Awareness of IT-related market trends (De Brentani and Kleinschmidt, 2004)	
Top management support	Awareness of competitors' initiatives (De Brentani and Kleinschmidt, 2004; Wu et al., 2003)	Srinivasan et al. (2002) and Wu et al. (2003)
	Belief of using IT (Srinivasan et al., 2002; Wu et al., 2003)	
	Top management actions	
	Support for IT investment (Howell and Higgins, 1990; Srinivasan et al., 2002)	
Organisational learning	Asking subordinates to be aware of the new IT trend (Ravichandran and Rai, 2000)	Cohen and Levinthal (1990), Hansen and Lovas (2004) and Scott (2000)
	Encouraging employees to be familiar with new IT applications (Ravichandran and Rai, 2000; Srinivasan et al., 2002)	
	Learning and training	
	Fast learning (Cohen and Levinthal 1990)	

**Table 2** Operational definitions of observed variables (continued)

<i>Variables</i>	<i>Operational definition and scale items</i>	<i>Sources</i>
Organisational learning	Providing business and technical training courses (Cohen and Levinthal, 1990)	Cohen and Levinthal (1990), Hansen and Lovas (2004) and Scott (2000)
	Information exchange/acquiring	
	Exchanging information freely and frequently (Cohen and Levinthal, 1990; Scott, 2000)	
Customer involvement	Substantial investment in acquiring R&D and business knowledge (Hansen and Lovas, 2004, Scott, 2000)	Gruner and Homburg (2000), Håkanson (1993), Nambisan (2002), Song and Adams (1993)
	Interaction intensity	
	Interacting with customers beyond the standards of market research (Gruner and Homburg, 2000; Nambisan, 2002)	
	The intensity of customer interaction was high (Gruner and Homburg, 2000; Nambisan, 2002)	
IT adoption for NPD	Interacted members	Basu and Kumar (2002), McGrath and Iansiti (1998), Mesihovic et al. (2004) and Nambisan (2003)
	A high number of persons were involved from customer companies (Håkanson, 1993; Song and Adams, 1993)	
	The number of involved companies was high (Song and Adams, 1993)	
	Process/project management	
	Integrity of data collection (Mesihovic et al., 2004)	
	Integrated process analysis and planning (Basu and Kumar, 2002; Nambisan, 2003)	
	Project coordination (McGrath and Iansiti, 1998; Mesihovic et al., 2004)	
Project monitoring and control (Mesihovic et al., 2004)		
IT adoption for NPD	Knowledge management	Alavi and Leidner (2001), Baba and Nobeoka (1998), Joshi and Sharma (2004), Kappel and Rubenstein (1999), Kyriakopoulos and de Ruyter (2004), Nambisan (2003), Wasko and Faraj (2000)
	Creation of corporate knowledge directories as the mapping of internal expertise (Alavi and Leidner, 2001)	
	Sharing knowledge (Joshi and Sharma, 2004; Nambisan, 2003; Wasko and Faraj, 2000)	
	Accessing to information on past projects (Baba and Nobeoka, 1998; Nambisan, 2003)	
	Enhancing creativity (Kappel and Rubenstein, 1999; Kyriakopoulos and de Ruyter, 2004)	
Collaboration management	Routine reporting to collaborators (Boutellier et al., 1998; Hameri and Nihtilä, 1997; Hartley, 1998)	Boutellier et al. (1998), Dahan and Hauser (2001), Håkanson (1993), Hameri and Nihtilä (1997), Hartley (1998), Nambisan (2003), Noori and Lee (2004) and Sprow (1992)
	Exploiting co-developed know how of collaborators (Dahan and Hauser, 2001; Noori and Lee, 2004; Sprow, 1992)	

**Table 2** Operational definitions of observed variables (continued)

<i>Variables</i>	<i>Operational definition and scale items</i>	<i>Sources</i>
IT adoption for NPD	Sharing and protecting shared patents of collaborators (Håkanson, 1993) Co-managing NPD team with collaborators (Boutellier et al., 1998; Hartley, 1998; Nambisan, 2003)	Boutellier et al. (1998), Dahan and Hauser (2001), Håkanson (1993), Hameri and Nihtilä (1997), Hartley (1998), Nambisan (2003), Noori and Lee (2004) and Sprow (1992)
Design customisation	Design customisation requirements Possessing product variety (Gilmore and Pine, 1997; Tu et al., 2004) Meeting customers' requirements (Gilmore and Pine, 1997; Lampel and Mintzberg, 1996; Tu et al., 2004) Possessing design modularity (Mikkola, 2003; Tu et al., 2004) Design customisation delivery Customisation with high quality (Da Silveira et al., 2001; Kay, 1993) Customisation with low cost (Da Silveira et al., 2001; Kay, 1993) Customisation with fast development (Da Silveira et al., 2001)	Da Silveira et al. (2001), Gilmore and Pine (1997), Kay (1993), Lampel and Mintzberg (1996), Mikkola (2003) and Tu et al. (2004)
NPD success	NPD customer satisfaction Conformance to customer requirements (Garvin, 1984; Gruner and Homburg, 2000) Conformance to technical capabilities (Gruner and Homburg, 2000) NPD financial performance Satisfaction of financial success (Griffin and Page, 1993; Gruner and Homburg, 2000; Olson et al., 1995) Satisfaction of project expense control (Olson et al., 1995) NPD process performance Timeliness of market launch (Griffin and Page, 1993; Gruner and Homburg, 2000) Satisfaction of the development process (Griffin and Page, 1993; Gruner and Homburg, 2000)	Garvin (1984), Griffin and Page (1993), Gruner and Homburg (2000) and Olson et al. (1995)

**Table 3** Summary statistics and correlation matrix of observed and control variables

	Mean	Std. dev.	No. of items	Alpha	1	2	3	4	5	6	7	8	9	10	11
1 IT adoption for NPD	3.889	0.529	12	0.887											
2 Design customisation	3.818	0.580	6	0.815	0.499*										
3 NPD success	3.780	0.548	6	0.776	0.570*	0.632*									
4 IT behavioural belief	4.073	0.492	4	0.800	0.514*	0.345*	0.382*								
5 Top management support	3.941	0.599	6	0.869	0.560*	0.453*	0.468*	0.523*							
6 Organisational learning	3.746	0.689	4	0.800	0.616*	0.520*	0.526*	0.427*	0.637*						
7 Customer involvement	3.519	0.720	4	0.859	0.509*	0.490*	0.474*	0.263*	0.466*	0.497*					
8 R&D ratio	2.535	0.696	1		0.243*	0.243*	0.275*	0.112	0.198*	0.294*	0.210*				
9 Years since established	3.861	1.126	1		-0.012	-0.012	-0.017	0.005	-0.070	0.060	-0.098	-0.083			
10 Firm capital	3.331	1.491	1		0.099	0.059	0.087	0.128	0.040	0.120	-0.022	0.273*	0.282*		
11 Firm revenue	3.145	1.367	1		0.073	0.055	0.086	0.075	0.082	0.139	0.034	0.268*	0.325*	0.814*	
12 No. of employee	2.884	1.426	1		0.076	0.107	0.117	0.137	0.059	0.121	0.032	0.269*	0.329*	0.761*	0.759*

\*Correlation is significant at the 0.01 level (2-tailed).

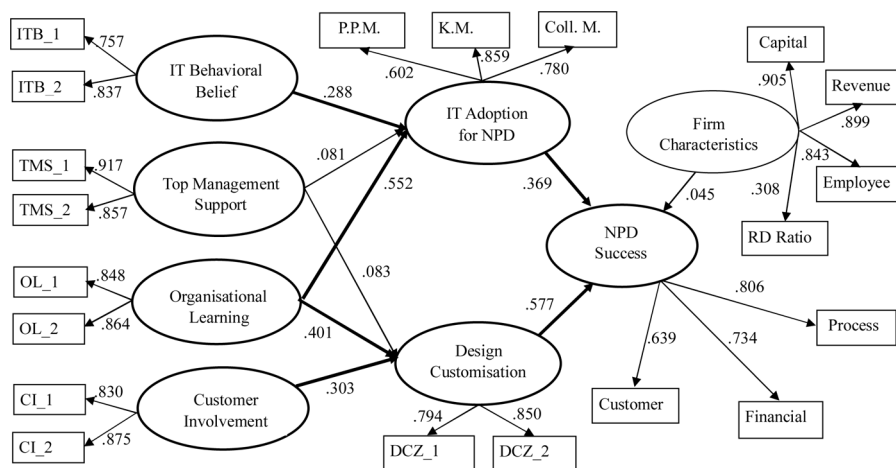


## 4 Analyses and results

### 4.1 Validation of measures

For validation purpose, we submitted the data to Confirmatory Factor Analysis (CFA) using AMOS 5.0. Without affecting the meaning of the scales, we deleted the items with factor loadings lower than 0.5 (Jöreskog and Sörbom, 1989). The model fit was assessed by four indices: the Goodness of Fit Index (GFI), Incremental Fit Index (IFI), Comparative Fit Index (CFI), and Root Mean Square Residual (RMR). Four first-order CFA models were examined. The first CFA model examines the validity of the antecedent constructs in the research model including constructs of IT behavioural belief, top management support, organisational learning, and customer involvement. The results show a statistically significant chi-square ( $\chi^2 = 255.696$ , degree of freedom [df] = 129,  $p < 0.001$ ) and acceptable fit indexes (GFI = 0.857; IFI = 0.917; CFI = 0.915; RMR = 0.034). The second CFA model examines the validity of the constructs of IT adoption for NPD in the research model. The results show a statistically significant chi-square ( $\chi^2 = 118.522$ , df = 51,  $p < 0.001$ ) and acceptable fit indexes (GFI = 0.901; IFI = 0.925; CFI = 0.924; RMR = 0.036). The third CFA model examines the validity of the design customisation construct in the research model. The results show a statistically significant chi-square ( $\chi^2 = 20.138$ , df = 8,  $p < 0.01$ ) and acceptable fit indexes (GFI = 0.965; IFI = 0.963; CFI = 0.964; RMR = 0.032). The last CFA model examines the validity of the NPD success construct in the research model. The results again show a statistically significant chi-square ( $\chi^2 = 25.819$ , df = 6,  $p < 0.001$ ) and acceptable fit indexes (GFI = 0.954; IFI = 0.923; CFI = 0.920; RMR = 0.032). All these statistics support the model fit and the validity of the measures of the different constructs in the research model. The significant factor loadings of these CFA models are exhibited in Figure 2.

**Figure 2** SEM analysis result (Model I: full mediation model)



Furthermore, construct reliabilities of the scales were tested by means of Cronbach's alpha. The reliability coefficients of all measures, as shown in Table 3, are greater than 0.73, which is deemed acceptable (Nunnally and Bernstein, 1994). The characteristics of

the sample firms are exhibited in Table 4. In the sample, 38.4% of the firms were established more than 15 years ago; 37.2% of the firms have firm capital more than USD66 millions; 27.3% of the firms have annual revenue more than USD 330 millions. Moreover, 65.1% of firms have R&D spending ratio more than 2%, and 23.3% of firms have more than 2000 employees.

**Table 4** Characteristics of the sample firms

<i>Variable</i>	<i>Category</i>	<i>N</i>	<i>Rate (%)</i>
Years since established	1 <3 years	6	3.5
	2 3~5 years	14	8.1
	3 6~10 years	44	25.6
	4 11~15 years	42	24.4
	5 >15 years	66	38.4
	<i>Aggregate</i>		<i>172</i>
Firm capital (1 US dollar = 30.5 NT dollars)	1 <USD 3.3 millions	22	12.8
	2 USD 3.3~16.5 millions	41	23.8
	3 USD 16.5~33 millions	31	18.0
	4 USD 33~66 millions	14	8.1
	5 >USD 66 millions	64	37.2
	<i>Aggregate</i>		<i>172</i>
Firm annual revenue (see exchange rate above)	1 <USD 3.3 millions	15	8.7
	2 USD 3.3~33 millions	57	33.1
	3 USD 33~165 millions	35	20.3
	4 USD 165~330 millions	18	10.5
	5 >USD 330 millions	47	27.3
	<i>Aggregate</i>		<i>172</i>
% of R&D spending to annual revenue	1 <1%	20	11.6
	2 1~2%	40	23.3
	3 >2%	112	65.1
	<i>Aggregate</i>		<i>172</i>
No. of employee	1 <100	26	15.1
	2 100~500	67	39.0
	3 500~1000	20	11.6
	4 1000~2000	19	11.0
	5 >2000	40	23.3
	<i>Aggregate</i>		<i>172</i>

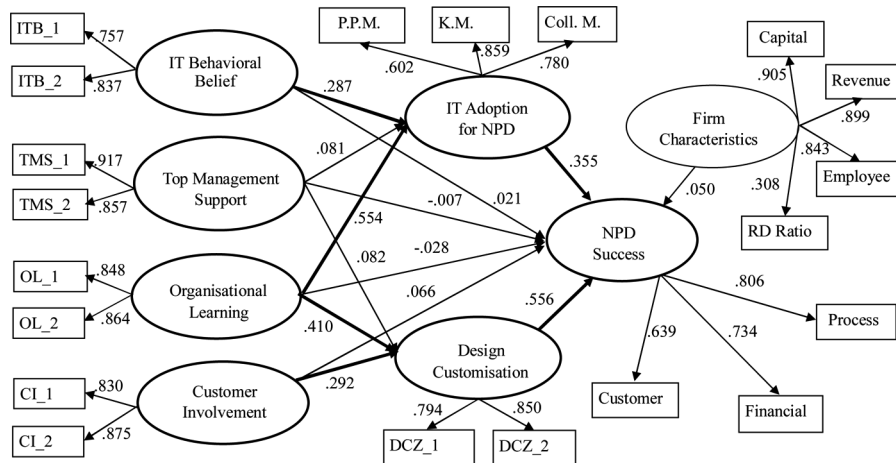
#### 4.2 Hypotheses testing

To test our proposed model and hypotheses, the Structural Equation Modelling (SEM) method in AMOS 5.0 is used. Specifically, a two-step SEM procedure is applied (Tanriverdi, 2005). In the first step, a second-order factor analysis is conducted for each

of the observed constructs. The efficacy of second-order CFA models is assessed through examination of the target (*T*) coefficient, which is the ratio of the chi-square value of the first-order model to the chi-square value of the second-order model (Marsh and Hocevar, 1985; Segars and Grover, 1998). This *T* coefficient is no more than 1 and higher value means that the relationship among first-order factors is sufficiently captured by the higher-order factors. In our model, four second-order CFA results are obtained and compared with the four corresponding first-order CFA results. The *T* values for the observed variables, IT adoption for NPD, design customisation, the four antecedents and NPD success are all close to 1, confirming the efficacy of these second-order CFA models.

In the second step, two SEM models are developed. The first model (Model I), as depicted in Figure 2, posits that IT adoption for NPD and design customisation fully mediate the effects of IT behavioural belief, top management support, organisational learning and customer involvement on NPD success. As depicted in Figure 3, the second model (Model II) tests for the partial mediating effects of IT adoption for NPD and design customisation. As such, both direct and indirect effects of IT behavioural belief, top management support, organisational learning and customer involvement are modelled. This approach to mediation testing is consistent with other studies examining mediation hypotheses (e.g., Morgan and Hunt, 1994; Brown et al., 2002). Additionally, the factor of firm characteristics, consisting of firm capital, firm annual revenue, R&D spending ratio and number of employees, is included in the two SEM models as the control variable to eliminate the unobserved effects. Neither model shows any significant effect on NPD success. Note that ‘year since established’ discussed previously is dropped because its factor loading is low (0.30) and it does not reveal significant correlation with any research variable (see Table 3).

Figure 3 SEM analysis result (Model II: partial mediation model)



The analyses of Model I and Model II reveal that both models possess model fit. For Model I, the results show a statistically significant chi-square ( $\chi^2 = 200.017$ ,  $df = 151$ ,  $p < 0.001$ ) and acceptable fit indexes (GFI = 0.896; IFI = 0.901; CFI = 0.973; RMR = 0.037). For Model II, the results also show a statistically significant chi-square ( $\chi^2 = 199.595$ ,  $df = 147$ ,  $p < 0.001$ ) and acceptable fit indexes (GFI = 0.896;

IFI = 0.901; CFI = 0.971; RMR = 0.036). To determine whether a fully mediated model (Model I) better fits the data than a partially mediated model (Model II), a  $\chi^2$  difference test is conducted. The results indicate no significant difference between the models ( $\chi^2$  difference = 0.422,  $df = 5$ ,  $p > 0.05$ ). We, therefore, further apply the four criteria developed in the Morgan and Hunt (1994) and James et al. (1982) studies for comparing the fit of SEM models:

- overall fit of the model as measured by CFI
- percentage of the models' hypothesised parameters that are statistically significant
- Squared Multiple Correlations (SMCs) of dependent variables
- parsimony as measured by Parsimonious Normed Fit Index (PNFI).

When applied to Models I and II, the first criterion favours the fully mediated model (Model I) as 6 of the 9 paths are supported (at least  $p < 0.05$ ) in contrast to 13 (at least  $p < 0.05$ ) for the partial mediated model (Model II). Yet, no significant differences were found according to the other three criteria.

Given that the fully mediated SEM model (Model I) has a better fit, we test only its associated hypotheses. The analysis supports  $H_1$  and suggests that IT adoption for NPD has a positive impact on NPD success ( $b = 0.369$ ,  $p < 0.001$ ). It also appears that design customisation has a similar effect on NPD success ( $H_2$ ). The effect of design customisation on NPD success ( $b = 0.577$ ,  $p < 0.001$ ) is positive and significant. Thus,  $H_2$  is supported. For the impacts of antecedents on IT adoption for NPD, the structural links from IT behavioural belief ( $b = 0.288$ ,  $p < 0.05$ ) and organisational learning ( $b = 0.552$ ,  $p < 0.001$ ) to IT adoption are both positive and significant and provide empirical support for  $H_3$  and  $H_5$ . Similarly, for the impacts of antecedents on design customisation, the structural links of organisational learning ( $b = 0.401$ ,  $p < 0.05$ ) and customer involvement ( $b = 0.303$ ,  $p < 0.05$ ) to design customisation are both positive and significant and provide empirical support for  $H_7$  and  $H_8$ . However, the structural links of top management support to IT adoption for NPD ( $b = 0.081$ ,  $p > 0.1$ ) and design customisation ( $b = 0.083$ ,  $p > 0.1$ ) are both insignificant, thus  $H_4$  and  $H_6$  are not supported. Note that, from the bivariate correlation analysis, the result shows that top management support is highly correlated with IT adoption for NPD and design customisation. However, while SEM approach is used and all antecedent effects are considered simultaneously, the effects of top management support on IT adoption for NPD and design customisation are not significant.

Furthermore, a scrutiny of both Model I and Model II reveals that the direct effects of IT behavioural belief, top management support, organisational learning and customer involvement on NPD success are insignificant with the mediation of IT adoption for NPD and design customisation. In contrast, the results indicate that IT behavioural belief has a positive and indirect impact on NPD success through the mediation of IT adoption for NPD; organisational learning has a positive and indirect impact to NPD success through the mediation of both IT adoption for NPD and design customisation; customer involvement has a positive and indirect impact on NPD success through the mediation of design customisation. The aforementioned results support  $H_9$  of this study. However, the effects of top management support on IT adoption for NPD and design customisation are not supported. In addition, the indirect impact of top management support on NPD success is not as strong as we expected.

## **5 Discussions and implications**

### *5.1 The effects of IT adoption on NPD success*

In this study, IT adoption for NPD is examined through process/project management, knowledge management and collaboration management. The results of statistical analysis support our hypothesis of the positive impact of IT adoption on NPD success. A follow-up field study reveals that these Taiwanese manufacturing firms have adopted modern IT applications to cope with complicate design processes, short design cycles and fast response time. Basic IT applications such as e-mail systems and Intranet workflow applications have been used organisational-wide to provide communication channels across departments and among employees. In addition, many firms have established their web portals that not only provide an external access to outside customers and general public, but also maintain an internal access window for corporate use. Particularly, for R&D and manufacturing departments, the Intranet systems are frequently used to keep track of project progress, assign and monitor jobs, and document various kinds of information.

Whether the new product can be launched on schedule relies heavily on the continuous monitoring of the project progress. With the use of IT applications, it is easier for managers to control projects, detect problems and get helps at the earlier stage. Additionally, the design processes can be improved continuously by frequent communication among project members and providing an easier access to past design archives. The basic idea of concurrent engineering is to remove the 'throw over the wall' mindset among employees in different departments and to consider marketing, manufacturing, assembly, and after-sell service issues earlier in the design stage. Adopting IT applications has helped these firms to facilitate concurrent engineering concepts by providing better communications among people from different departments earlier.

Using IT applications for NPD also helped the firms to ensure higher product design quality. 'Quality at the source' is a well recognised concept that suggests controlling product quality at the earliest stage as much as possible. For example, if the products can be well designed; materials purchased are in good and consistent quality; facilities are maintained regularly, and employees are well trained, then the targeted product quality can be easier achieved with a lower cost (i.e., lower prevention cost). IT applications have been widely used for quality control and management. In addition to provide functions of data and information documenting and retrieving, IT applications have also been used for product quality design, analysis and testing. Many quality analysis tools are developed as computer software or systems so that employees in the R&D and manufacturing departments can use them for their quality control purposes. Adopting IT applications for quality testing is not only for mass production stage but also for product design stage. Simulation techniques are widely used to imitate the real production run and to test product manufacturability and productivity. IT applications are also frequently adopted to test product reliability for quality conformance. New product quality is crucial for NPD success and IT adoption has proven to be a key to improve NPD performance among the sample firms. The successful IT adoption of Taiwanese manufacturing firms could serve as a road map for their counterparts in many developing countries around the world.

### *5.2 The effect of design customisation on NPD success*

The SEM results show a positive and significant effect of design customisation on NPD success. Nowadays, companies in consumer market strive for providing the right product to the right customer in the right place and at the right time. Our sample firms are no exception. It is vital for the firms to serve their business clients' needs by quickly reacting to the clients' downstream customers' needs. These needs are required to be detected and fulfilled earlier during the NPD process. The task of 'customisation' is performed, therefore, not only in the selling and delivery stages, but also early in the design stage.

Providing tailor-made products to customers has been a common practice for many of our sample firms. Build-to-Order (BTO) and Configure-to-Order (CTO) concepts have been widely adopted especially for firms in IT industry. The OEM and ODM companies usually do not have the final products stockpiled; they would only trigger the order fulfilment process if the order is received. The major challenges for BTO and CTO practices are not only to reduce inventory cost but also be responsive to customers' orders with small lot sized and various product types. To deliver customised products in a streamline manufacturing environment, it definitely requires products be designed for easy customisation in an acceptable time frame.

Many of the sample firms apply the concepts of group technology and modularity to increasing customisation capability. One of the merits of adopting group technology is to avoid 'reinventing the wheel' for new product design. Part and product coding systems are developed through the process of group technology. The product codes are usually numbered according to the similarity between parts. This would make R&D staff easier to retrieve information about parts and components from the coding systems. This in turn facilitates modular design. Through the use of group technology and modular design, many of our sample firms are able to achieve higher customised product quality, lower cost, and faster response time.

### *5.3 The antecedents of IT adoption for NPD and design customisation*

The antecedents of IT adoption for NPD and design customisation considered in this study are: IT behavioural belief, top management support, organisational learning and customer involvement. From the results of analysis, three of the antecedents have significant effect on IT adoption for NPD and design customisation, except top management support. To successfully adopt IT for NPD practices, firms need to put emphases on improving employees' perception towards IT use. Our results confirm with previous study and show that higher IT behavioural belief would yield higher degree of IT adoption for NPD. One plausible approach to create higher IT behavioural belief is to improve the employees' IT skills and knowledge as well as understanding job requirements. Moreover, it may be accomplished by creating an advanced IT environment that facilitates employees' learning by doing.

Organisational learning has shown the strongest association with IT adoption. Continuous learning is important for R&D staff to keep abreast of the latest technological developments as well as the current and future market trend. Organisational learning can proceed with intellectual exchanges and communications among employees. Organisations with higher learning spirits tend to adopt more IT applications for NPD and better design customisation. Further, the SEM results show strong impacts of customer involvement in building customisation capability. This implies that inviting

customers in earlier design stage could understand customer needs and requirements earlier.

#### *5.4 The mediating effects of IT adoption for NPD and design customisation*

Despite the direct impacts of the four antecedents on NPD success previously reported in the literature, this study shows that IT adoption and design customisation fully mediate the effects of these antecedents. One plausible explanation is that IT behavioural belief, top management support, organisational learning and customer involvements are static in nature and represent organisational characteristics, while IT adoption and design customisation are action-oriented and dynamic. The latter two dynamic actions are the key to producing the performance outcome of an organisational process such as NPD. This implies that the proper way of explaining the causal effects on performance outcome is to move from static attributes to dynamic actions and, finally, to performance outcome.

## **6 Conclusions and recommendations**

NPD process is hard to manage but important in today fiercely competitive business environment. In this paper, the factors influencing NPD success are studied. The results contribute to the growing body of literature by linking IT adoption, design customisation with NPD success and providing a framework for understanding how IT may be appropriately viewed as an enabler for NPD practices and how design customisation will affect NPD success. More importantly, it is one of the few studies to provide an empirical evidence for the effects of IT adoption and design customisation on NPD success. It operationalises IT adoption for NPD practices with three dimensions: process/project management, knowledge management and collaboration management. It also develops the notion of using IT adoption for NPD and design customisation as action-oriented mediators that are supported by the organisational characteristics of IT behavioural belief, top management support, organisational learning and customer involvement. The empirical analysis examines the causality from antecedents to IT adoption for NPD and design customisation and, in turn, to NPD success. The results reveal that most causal relationships are positive and significant.

By establishing the significant links between IT adoption, design customisation and NPD success, this study shows business managers that firms should fully adopt IT for NPD processes and devote themselves to building up design customisation capability. Through grounded theories and empirical evidences, this study shows why IT adoption for NPD and design customisation are important to NPD success. To achieve NPD success, business managers should pay more attention to how to adopt IT strategically and how to foster design customisation operationally.

## **7 Limitations and future studies**

From our analytical results, we suggest that the effects of IT behavioural belief, organisational learning and customer involvement on NPD success are explained and mediated by IT adoption and design customisation. However, there are still other factors related to NPD success that are not considered in our study. For example,

manufacturability, marketing channel and logistics are three possible mediators. It is well known that Ericsson AB, one of the pioneers in mobile phone networks and devices, began its alliance with Sony Corp. in October 2001 because before then it was losing revenue for every mobile phone it sold. Ericsson is an excellent innovator and develops great new product. However, its manufacturability, marketing channel and logistics are inferior to Sony Corp. Using Sony's extant advantages, Sony-Ericsson was able to turn the situation around and started to rake in profit from their mobile phone sales. Future studies may introduce these three factors as the mediators.

An inherent limitation of self-report scores collected and analysed by this study is that they may not represent the actual conditions; rather, they are perceptions of the respondents towards the conditions. Another limitation comes from the scores of NPD success collected from the R&D managers, which might introduce common method biases (Podsakoff et al., 2003). Our data validation process reveals that the reliability of this construct is acceptable and that the scale items fit well in the three-factor construct, rather than falling into one single factor, during the CFA process. Although these results indicate the absence of significant bias, future research may invite customers, financial managers and marketing managers to jointly evaluate this success factor. Moreover, the survey is based on manufacturing firms listed as Taiwan's 5000 largest companies, and caution is advised when applying the findings to firms in other industries or countries. Future research directions of this study may include investigations of other factors affecting NPD success, or a cross-country comparison to see the differences among various cultures. Whether there is a relation between IT adoption and design customisation and what tactics can be used to increase the effect of IT adoption and design customisation are also important issues and need to be addressed in a future study.

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## **Appendix: Survey questionnaire items**

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### *IT adoption for NPD*

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#### *Process/project management: In our department*

- PPM\_1 IT was adopted for R&D data collection and storage
- PPM\_2 IT was adopted for NPD process analysis and planning
- PPM\_3 IT was adopted for NPD project coordination
- PPM\_4 IT was adopted for NPD project monitoring and control

#### *Knowledge management: In our department*

- KM\_1 IT was adopted to create internal knowledge database
- KM\_2 IT was adopted to enable knowledge sharing
- KM\_3 IT was adopted to enable retrieval of past R&D project information
- KM\_4 IT was adopted to enhance employee creativity and design capability

#### *Collaboration management: In our department*

- CM\_1 IT was adopted for routine reporting to managers of other departments and/or partners
- CM\_2 IT was adopted to exploit co-developed know-how of other departments and/or partners
- CM\_3 IT was adopted to share and protect co-owned commercial rights of other departments and/or partners
- CM\_4 IT was adopted to co-manage the NPD team with other departments and/or partners

#### *Design customisation: In our department*

- DCZ1\_1 We are capable of designing various products for different customers
- DCZ1\_2 We possess modular design capability
- DCZ1\_3 Our design customisation capability meets customers' requirements
- DCZ2\_1 We are capable of customising product at low cost (related to competition)
- DCZ2\_2 We are capable of customising product with high quality (related to competition)
- DCZ2\_3 We are capable of customising product with fast development and delivery (related to competition)

#### *IT behavioural belief: In our department*

- ITB1\_1 The use of IT increases R&D management efficiency
- ITB1\_2 The use of IT increases employee performance
- ITB2\_1 The IT applications are easy to use
- ITB2\_2 The IT applications are easy to understand
-

**Appendix: Survey questionnaire items (continued)***IT adoption for NPD**Top management support: In our company*

- TMS1\_1 Top managers are aware of recent IT development  
 TMS1\_2 Top managers are aware of competitors' new movements in using IT  
 TMS1\_3 Top managers believe the use of IT is beneficial  
 TMS2\_1 Top manager frequently ask subordinators to be aware of new IT trends  
 TMS2\_2 Top managers provide sufficient supports for IT investment  
 TMS2\_3 Top managers encourage employees to be familiar with new IT applications

*Organisational learning: In our department*

- OL1\_1 We learn fast about how to use new technologies  
 OL1\_2 We have provided many R&D and IT training courses for managers and technicians  
 OL2\_1 We exchange information frequently  
 OL2\_2 We have invested a lot on acquiring R&D and IT knowledge

*Customer involvement: While designing new product*

- CI1\_1 We interacted with customers closely  
 CI1\_2 The intensity of customer interaction was high  
 CI2\_1 Many persons were involved from customer companies  
 CI2\_2 Many companies were involved

*NPD success: In our company*

- NPDS\_1 We design new products to conform with customers' requirements  
 NPDS\_2 We possess technical capabilities of NPD (related to competition)  
 NPDS\_3 We have developed new products with financial success  
 NPDS\_4 NPD project expenses have been under control  
 NPDS\_5 New products have been timely launched  
 NPDS\_6 We have satisfied with the development process