Research on the Influences of New Product Design and New Product Development Process Management on New Product Development Performance in Taiwan's Industries

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Abstract

This study aims to probe into the influence of new product design and new product development process management on development performance. The research finding demonstrates that product design reveals positive and significant influence on new product development performance. Through statistical analysis, this study finds that companies in Taiwan value new product design. When companies value it more, they tend to have better new product development performance. With regard to the relation between new product development process management and new product development performance, the empirical results demonstrate that companies would pay more attention on new product development process management. With regard to new product idea and assessment, concept design and development, product function test and mass production in the market, through statistical analysis, this study finds that companies that value process management of new product development tend to have better new product development performance. As to the influence of new product design and new product process management on new product development performance, statistical analysis result demonstrates that the integration between new product design valued by companies in Taiwan and development process management would lead to significantly positive influence on new product development performance of the companies.

Key Words: New Product Design, New Product Development Process Management, New Product Development Performance

1. Introduction

This study probes into new product design and new product development process management and intend to further recognize new product development performance. Innovation is

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the important issue in the 21st century and innovative management becomes necessary for sustainable development. In order to pursue economic development and competitiveness, companies should value their innovative management and fulfill the goal of sustainable operation by effective innovative management (Tien *et al.*, 2007). In competitive time, in order to survive and have sustainable competitive advantages, most of companies focus on "new product design" and "new product development process management" to upgrade the operational performance. Upon the above two factors, this study intends to conduct in-depth research on the influence of new product design and new product development process management on new product development performance in new product development. Through empirical analysis, this study will find the relation between new product design and new product development process management to lead to better new product development performance. Based on above motives, the purposes of this study include below: (1) to recognize the relation between new product design and new product development performance; (2) to probe into the relation between new product development process management and new product development performance; (3) to probe into the influence of integration of new product design and new product development process management on new product development performance.

2. Literature Review

2.1 Product design

The term "Design" derived from "Designare" in Latin and it meant some plans could be changed generation after generation. It emphasized the planning and organizational process and the output of the planning. Sharon (1984) suggested that fashion design referred to the selection of various forms of products Crawford (1994) indicated that new product development could be divided into Brand New Product, Upgrade or Cost Reduction and Customization. Kotler and Alexander (1984) suggested that "product design" was the major tool for companies to have competitive advantage differentiation. The study of Walsh (1995) and Nixon (1999) on the classification and generalization of design function indicated that upon different functions, new product design included engineering design and industrial design. Walsh (1995) suggested including human engineering in the scope of engineering design. Nixon (1999) also suggested the same idea that industrial design not only included the planning of product appearance aesthetics, but also involved product planning and design and market image for the consumers. Page and Herr (2002) suggested that product design included two aspects: (1) product function; (2) aesthetics of product appearance. Upon literature review, Creusen and Schoormans (2005) conducted the study on the influence of different product appearances on the consumers' selection and allocated six roles of product ap-

pearance for the consumers: (1) aesthetics communication; (2) symbolism; (3) function; (4) human information; (5) attraction; (6) classification. In the study on furniture industry, Chang and Hsu (2005) divided product design characteristics below: (1) function; (2) operation; (3) appearance.

French design group GBJ (Groupe Bernard Juilhet, 1995) studied 565 enterprises in France and found that corporate investment in new product design positively influenced corporate image, product appearance and customer satisfaction. Yamamoto and Lambert (1994) demonstrated by Conjoint Scaling Approach that the appearance of products would influence the evaluation of the products. In some situations, the influence of product appearance could be more significant than those of product efficacy and price. Bloch (1995) proposed a conceptual framework on product design and elaborated how product design influenced the consumers' psychological and behavioral reactions. Walsh (1995) suggested that engineering design referred to the planning of product functions, including R&D of product technological functions, components and structure, cost reduction, etc. McDonagh *et al.* (2002) suggested that design functions included two categories: (1) concrete function: practical production function, human engineering and appearance aesthetics communication; (2) emotional function: creating product culture and social value and constructing the emotional connection between the consumers and products. Gemser and Leenders (2001) suggested the transformation of product demand and conditions into materials, elements and components. Based on the literature above, this study treated engineering planning design, human engineering design, appearance aesthetic design and product image design as the function constructs of new product design.

2.2 New product development process management

Loch (2000) studied 90 high-tech companies in Europe, and suggested that a customer-oriented new product development project with completed designed process and assessment, cross-functional integration, high-rank supervisors' support and powerful execution would be the success factors for companies. Iansiti (1996) suggested that with technology development and changeable market, every step in new product development process should be managed simultaneously upon high level of integration. Belliveau *et al.* (2004) indicated that the steps from new product concept development, design, manufacturing to marketing should be upon simultaneous approach to rapidly delivery the products to the consumers. When companies could be ahead in every process of new product development, they would accomplish market share and profits. Thomas (1993) indicated that from the view of product development process, different firms would have different types of product development according to corporate and product characteristics: (1) sequential new product development; (2) holistic new product development; (3) overlapping new product development; (4) chaotic new product development.

Brown and Svenson (1988) suggested that R&D was regarded as one system, including input, manufacturing and output. Assessment system included five stages: R&D input, R&D processing system, R&D output, R&D receiving system and outcomes and output, feedback to study the productivity of R&D. Cooper and Kleinschmidt (1997) divided new product development process into 7 steps and the process became the criterion for most of the business circle at present and it included: (1) Idea; (2) Preliminary Assessment; (3) Concept; (4) Development; (5) Test; (6) Trial; (7) Launch.

Veryzer (1998) suggested 8 steps of new product development: dynamic trend, convergence stage, forming stage, initial design, assessment preparation, prototype construction, test design, prototype and commercialization. Hisrich and Peters (1986) suggested that typical product development process: (1) idea generation; (2) screening; (3) business analysis; (4) development; (5) testing; (6) commercialization. Crawford (1994) indicated that the key success factors of new product development involved the close connection between the consumers and users, user satisfaction and value and sense of privilege for the users. The said researcher has defined the consumer demand, proper introduction in the market, positive product quality, compatibility of product and marketing personnel and after-assessment and tracking. Based upon above, this study treats (1) new product idea and assessment; (2) new product concept design and development; (3) new product-test and trial; (4) new product mass production in the market as the constructs of new product development process management.

2.3 New product development performance

Cooper and Kleinschmidt (1997) indicated five factors of new product development on performance: complete new product development process and plans, specific new product development strategy, corporate culture and high-rank supervisors' involvement in new product development. With regard to the professional managers of new product development, Olson *et al.* (1995) suggested that they should probe into the indexes such as new product quality of new product design, design satisfaction, time consumption for profit and loss balance, accomplishment of sell goal, budget control and time control of special projects. Terwiesch *et al.* (1998) studied 86 companies of 12 electronic industries around the world, and demonstrated the close relation between new product development process and the profits of the large-scale enterprises with more market share. Oliver *et al.* (2004) suggested that new product development performance should be valued upon cost, lead time, external and internal quality, schedule following and product profits.

Keegan *et al.* (1989) suggested that traditional performance measurement system tended to base on financial characteristics in financial statement. Upon these indexes, the companies evaluated performance of the departments and analyzed the difference between the measurement results and fixed criteria. Lynch and Cross (1991) suggested the problems of finance-

based performance measurement system: (1) it focused on the improvement of performance of the departments instead of the process performance; (2) it could not measure high-rank managers and there was no cost return; (3) measurement indexes and corporate strategic vision were inconsistent and unrelated; (4) information feedback tended to be deferred.

Cross and Lynch (1990) proposed the pyramid of performance and transformed strategic vision into business criteria. They suggested that the supervisors should construct overall strategic vision and then fulfill the individual goals Levitt and Pheodore (1966) suggested that most of product innovations were not simply the innovation; they were the imitation and improvement. They defined product innovation as "simple innovation" and "imitation." From the view of the producers,

Souder (1988) suggested that new product refers to products that company never produced before. Olson *et al.* (1995) compared 12 companies in different industries, including 45 new product development projects. The questionnaire included three constructs: product and finance, efficiency and psychology. Song and Montoya-Weiss (1998) suggested that new product development performance could be measured by new product effectiveness and new product efficiency.

In the study on Fortune 500 and Japanese enterprises, Souder and Song (1997) indicated that right product design and market selection would influence new product development performance, and emphasized that the companies should perceive the uncertainty of the market. They treated the following as the measurement indexes of new product development performance; (1) new products matches the expected time to the market; (2) consistency between new product development cost and budget; (3) new product matches the expected rates; (4) new products meet the expected sales; (5) new products match the expected market share; (6) the contribution of new products to corporate image; (7) contribution of new products to upgrade the corporate techniques; (8) the employees' cognition of the customers' satisfaction with new products; (9) the supervisors' satisfaction with new products. Based on above, this study generalizes the following constructs: (1) R&D performance; (2) financial performance of new product development performance.

3. Research Method

The approach of this study includes research framework and hypotheses.

3.1 Research framework

This research framework is shown in Figure 1, including new product design, new product development process management and new product development performance.

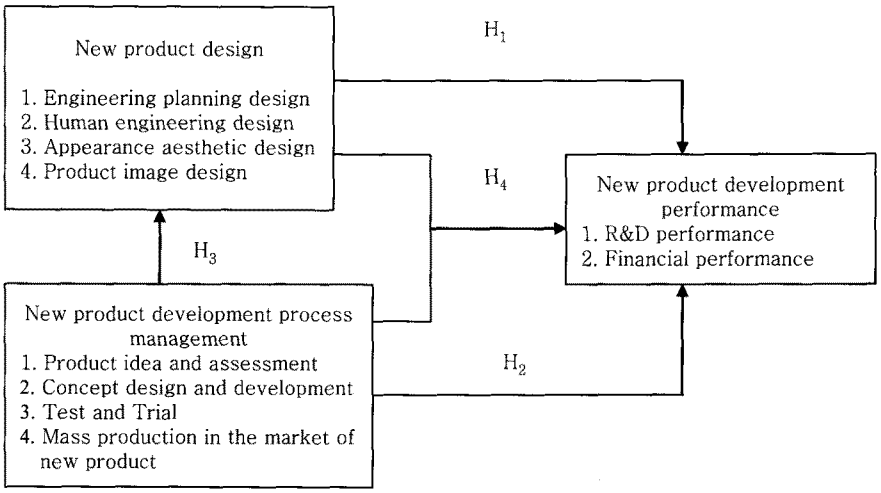


Figure 1. Research framework

3.2 Hypotheses

The following assumptions were used in this study:

H_1: Better new product design reveals more significant influence on new product development performance.

$H_{1\text{-}1}$: Better engineering planning design of new product reveals more significant influence on new product development performance.

$H_{1\text{-}2}$: human engineering design of new product reveals more significant influence on new product development performance.

$H_{1\text{-}3}$: Better appearance aesthetic design of new product reveals more significant influence on new product development performance.

$H_{1\text{-}4}$: Better Product image design of new product reveals more significant influence on new product development performance.

H_2: Better new product development process management reveals more significant influence on new product development performance.

$H_{2\text{-}1}$: Better new product idea and assessment reveals more significant influence on new product development performance.

$H_{2\text{-}2}$: Better concept design and development of new product reveals more significant influence on new product development performance.

$H_{2\text{-}3}$: Better new product-test and trial reveals more significant influence on new product development performance.

$H_{2\text{-}4}$: Better mass production in the market of new product reveals more significant influence on new product development performance.

H_3: Better new product development process management reveals more significant influence on new product design effect.

H_4: Integration of new product design and new product development process management reveals more significant influence on new product development performance.

4. Results and Analysis

4.1 Background analysis of the samples

This study treats high-tech companies in Taiwan as the questionnaire targets and the respondents are the participants in new product development, including project managers, the participants of new product development design and R&D and marketing personnel. There are 2,000 questionnaires distributed at the beginning of August 2008 and 460 of them were returned by October 2008. After eliminating 70 invalid samples, there are 390 valid questionnaires for statistical analysis upon Statistica 6.0. The valid and return rate is 19.5%.

4.2 Reliability and validity test

The questionnaire targets are the experts of high-tech industry. The design of the questionnaire is based on literature review. The content and terms of the draft questionnaires are modified to lead to validity and reliability. This study calculates Cronbach's α of the questions in each construct and validates reliability of the questions in the questionnaire. More Cronbach's α refers to higher level of correlation among the items and internal consistency. In basic studies, the scholar Nunnally (1978) suggested that reliability over 0.7 would be acceptable. Reliability of this study are more than 0.7. Thus, the internal consistency of the scales in this study is positive.

4.3 Descriptive statistics and factor analysis of product design

With regard to research framework of this study, new product design involves 4 constructs. After combination, there are totally 17 items. This study further extracts four factors by factor analysis and accumulated explained variance reaches 78.98%. The meanings of four factors are below: (1) factor 1 is named appearance aesthetic design which focuses on all approaches of appearance design; (2) factor 2 refers to engineering planning design; (3) factor 3 focuses on ergonomics and cognition of human engineering design and is named human engineering design; (4) factor 4 focuses on all approaches of product image design and it is named product image design. Factor analysis is shown in Table 1.

Table 1. Factor analysis of new product design

Names of factors		Appearance aesthetic design	Engineering planning design	Human engineering design	Product image design
Product design	Product process management	Factor 1	Factor 2	Factor 3	Factor 4
Appearance aesthetic design	Model management	0.5756	0.1978	0.5625	0.3623
	Material application	0.6061	0.4082	0.1909	0.1808
	Detail planning	0.5254	0.3528	0.2713	0.3714
	Product-test	0.5418	0.5084	0.1456	0.2457
	Color reaction	0.6467	0.1678	0.2893	0.2862
	Quality application	0.7459	0.3067	0.4132	0.3123
	Visual reaction	0.8013	0.2164	0.5266	0.5272
Engineering planning design	Product idea and assessment	0.1426	0.4165	0.2462	0.4273
	Quality engineering	0.1325	0.8917	0.1463	0.2463
	Concept design and development	0.2535	0.7813	0.5456	0.4572
	Technology function	0.2808	0.7708	0.5351	0.4352
Human engineering design	Ergonomics	0.3184	0.9306	0.1937	0.2938
	Cognition and idea	0.2813	0.8059	0.4706	0.4715
	Physical and mental comfort	0.1215	0.4135	0.6529	0.5528
Product image design	Mass production in the market	0.4449	0.1971	0.8237	0.5235
	Reflection of life style	0.2176	0.4072	0.8741	0.7731
	Reflection of habit	0.2793	0.2171	0.7795	0.8785
Eigenvalue		5.2727	2.1244	1.5507	1.9821
Explained variance		45.16%	18.40%	8.67%	8.75%
Accumulated explained variance		45.16%	61.56%	70.23%	78.98%

4.4 Relation between new product design, new product development process management and new product development performance

This study probes into the relation between new product design, new product development process management and new product development performance, and suggests that the companies which value new product design and new product development process management tend to have better new product development performance. In Model 1, new product design is treated as independent variable and new product development performance is regarded as dependent variables. In Model 2, new product development process management is treated as

independent variable and new product development performance is regarded as dependent variable for regression analysis. Multiple regression analysis is the extended application of simple correlation which is applied to find the straight line relation between prediction variable and criterion variable. Multiple regression analysis of this study is shown in Tables 2 and 3. According to the figures, B, F and P-Value all reach positive significance level. Equation of Model 1 (Table 2): $y_1 = 0.4658x_1 + 0.4749x_2 + 0.4947x_3 + 0.4549x_4 + e_1$ (engineering planning design is x_1, human engineering design is x_2, appearance aesthetic design is x_3 and product image design is x_4) which reveal positive and significant relation. Adjusted R is 0.799. Explanatory force of all variables is significant. Equation of Model 2 (Table 3): $y_2 = 0.4635x_5 + 0.4538x_6 + 0.4983\ x_7 + 0.4653\ x_8 + e_2$ (product idea and assessment is x_5, concept design and development is x_6, product-test and trial is x_7 and product mass production in the market is x_8) which reveals positive and significant relation. Adjusted R is 0.786. Explanatory force of all variables is significant. Thus, the correlation between new product design, new product development process management and new product development performance in this study is validated.

The result in Table 2 demonstrates significant and positive influence of new product design on new product development performance. In other words, the companies which value new product design tend to have better new product development performance. Coefficient of determination of regression analysis (R^2) is 0.3167 which is not high. Thus, new product design only involves 31.67% of variance of new product development performance. The factors such as "cross-department interaction and cooperation of R&D and marketing", "supplier involvement", "personal creativity" and "R&D management system" can influence new product development performance. Thus, the empirical result supports H_1, $H_{1\text{-}1}$, $H_{1\text{-}2}$, $H_{1\text{-}3}$ and $H_{1\text{-}4}$. In other words, with better product design, new product development performance will be more significant. The companies which value new product development process management tend

Table 2. Regression analysis of the constructs of new product design and new product development performance (Model 1)

Dependent variables / Independent variables	New product development performance			
	B	**R^2**	**F**	**P-Value**
New product design	0.5656	0.3167	28.309	0.000***
Engineering planning design	0.4658	0.3365	25.307	0.000***
Human engineering design	0.4749	0.3537	28.351	0.000***
Appearance aesthetic design	0.4947	0.3856	29.581	0.000***
Product image design	0.4549	0.3976	30.591	0.000***
Adjusted R	0.799			

Note: $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

to have better new product development performance. The result in Table 3 demonstrates the significantly positive influence of new product development process management on new product development performance. H_2, $H_{2\text{-}1}$, $H_{2\text{-}2}$, $H_{2\text{-}3}$ and $H_{2\text{-}4}$ are supported.

Table 3. Regression analysis of new product development process management and new product development performance (Model 2)

Dependent variables / Independent variables	New product development performance			
	B	R^2	F	P-Value
New product development process management	0.4431	0.3759	29.784	0.000***
Product idea and assessment	0.4635	0.3894	28.984	0.000***
Concept design and development	0.4538	0.3725	26.583	0.000***
Product-test and trial	0.4983	0.3539	29.576	0.000***
Mass production in the market	0.4653	0.3983	27.545	0.000***
Adjusted R	0.786			

Note: ***p < 0.01, **p < 0.05, *p < 0.1.

4.5 Relation between new product development process management and new product design

According to Table 4, the means of the constructs of new product development process management and new product design, through statistical analysis, are positive. Upon t-test, the correlation among the constructs reveals significance level. H_3 is validated.

Table 4. Relation between new product development process management and new product design

New product development process management	New product design				T value	Significance level (P-Value)
	Engineering planning design	Human engineering design	Appearance aesthetic design	Product image design		
Product idea and assessment	4.02	3.08	3.93	4.51	1.035	0.000***
Concept design and development	4.31	3.92	3.84	4.32	1.432	0.001***
Product-test and trial	4.45	3.73	3.88	4.05	1.539	0.003***
Mass production in the market	4.68	3.65	3.92	4.65	1.543	0.005***

Note: ***p < 0.01, **p < 0.05, *p < 0.1.

4.6 Influence of integration of new product design and new product development process management on new product development performance

This study then probes into the integration of new product development process management and new product design on new product development performance. Based on the target companies' pursuit of product design and new product development process management, this study integrates engineering planning design and human engineering design into engineering orientation, appearance aesthetic design and product image design into aesthetics orientation product idea and assessment and concept design and development into product development management; product-test and trial and product mass production in the market into product function management. This study divides the target companies into four groups: "product development management-engineering orientation", "product development management-aesthetics orientation", "product function management-engineering orientation" and "product function management-aesthetics orientation", as shown in Table 5. This study examines the four groups by One-way ANOVA and observes the difference of the means of new product development performance in different groups. The test result demonstrates that F is 13.137 which reaches significance level of $p < 0.01$. Thus, new product development performance of four combinations is not equal. Besides, new product development performances reveal significant difference among different combinations. H_4 is supported.

Table 5. Difference analysis of new product development performance of different combinations

	Product development management		Product function management		F	Significance level
	Engineering orientation	Aesthetics orientation	Engineering orientation	Aesthetics orientation		
New product development performance	3.8751	3.5266	3.5443	3.4249	13.137	0.000^{***}
	(0.1754)	(0.1901)	(0.2273)	(0.0835)		

Note: $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$. N.S. is insignificant; ( ) is standard deviation.

In order to find the difference of new product development performance in the companies with different product design orientations, this study conducts t-test on the means of new product development performance by pair combination to validate H_4. According to Table 6, when the companies have different functional product design orientations, their new product development performance will be significantly different. Besides, new product development performance of the companies with engineering orientation product design will be better than

those with aesthetics orientation.

Table 6. Difference analysis of integration of new product development process management

Integration between new product design and new product development process management	New product development performance		t value	Significance level
Product function management	Engineering orientation	4.9752	2.8879	0.0032***
	Aesthetics orientation	3.2271	2.8788	0.0051***
Product development management	Engineering orientation	4.5449	0.7821	0.2881N.S.
	Aesthetics orientation	3.2246	0.7719	0.2879N.S.

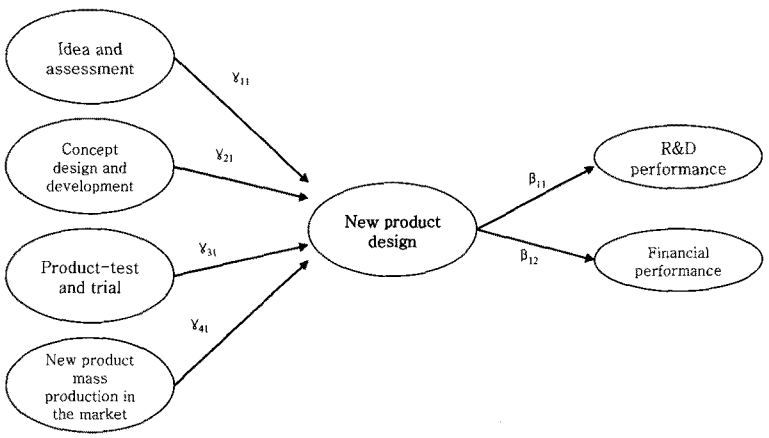
Note: ***P < 0.01, **P < 0.05, *P < 0.1, N.S. is insignificant.

4.7 LISREL analysis

Many scholars have proposed different indexes and criteria to find the fit of overall model. Bagozzi and Yi (1988) suggests GFI > 0.9, NFI > 0.9, CFI > 0.9, RMR > 0.05, RMSEA

Table 7. Fit indexes of hypothesis model and competition model

MODEL	GFI	NFI	CFI	RMR	RMSEA
Partially mediated model	0.92	0.93	0.95	0.03	0.05
Completely mediated model	0.99	0.98	0.96	0.05	0.00



$\gamma_{11} = 0.328$, $\gamma_{21} = 0.307$, $\gamma_{31} = 0.376$, $\gamma_{41} = 0.359$, $\beta_{11} = 0.436$, $\beta_{12} = 0.367$

Figure 2. Fittest model path (Completely mediated model)

< 0.05 to be the indexes of model fit. This study aims to probe into the relations of different constructs. The research framework is based on one hierarchy model (partially mediated model), as shown in Table 7. Fit Indexes are GFI = 0.92, NFI = 0.93, CFI = 0.95, RMR = 0.03 and RMSEA = 0.05. The fit matches the criteria suggested by above scholars. In fact, a set of research information involves many fit models which are not necessarily the best model. Based on competition model, this study compares hypothesis model and competition model of completely mediated and direct effect models and finds that completely mediated model is the fittest path. Fittest path relation of the constructs is shown in Figure 2.

5. Conclusions and Suggestions

5.1 Conclusions

With the change of time, the profits of manufacturing are reducing. The cost reduction which companies in Taiwan have relied on for long can no longer guarantee the growth. In recent years, more companies intend to create corporate differentiation through product design and increase the additional value of the products. In order to be different from the rivals and be accepted by the consumers, companies treat product design as the important media and tool. Through specific product design and new product development process management, companies increase the importance of the brands and products for the consumers and upgrade development performance of new products. The research findings are below:

1. As to the relation between new product design and new product development performance: the empirical result demonstrates that product design reveal significant and positive influence on new product development performance. Through statistical analysis, this study finds that companies in Taiwan value product design and tend to have better new product development performance when they value it more.
2. Relation between new product development process management and new product development performance: the result demonstrates that companies pay more attention on new product development process management and as to idea and assessment, concept design and development, product function test and mass production in the market of new products, through statistical analysis, this study finds that the companies which value new product development process management tend to have new product development performance.
3. Influence of integration of new product design and new product process management on new product development performance: the integration between new product design valued by companies and new product development process management, through statistical analysis, will reveal significantly positive influence on new product development

performance.

5.2 Management implications

5.2.1 Theoretical contribution

In terms of academic theories, the issues related to product design and new product process management are valued by many scholars and business circle in recent years and they are the key factors to create corporate differentiation and increase the additional value of the products. The contributions of this study for new product development performance are below:

(1) As to the relation between product design and the corporate performance, this study treats companies in Taiwan as the target, regards the importance of the product design functions as the measurement items of design and treats complete new product development performance as performance measurement index. It can reinforce the empirical result and this study also involves companies in Taiwan as the samples to validate the relation between product design and new product development performance.

(2) Domestic and foreign studies on new product development process management are mostly related to managerial field and focus on the consumers' views. This study includes process management in the research of new product development and measures new product development performance from the views of the managers and further probes into the influence of integration between process management and product design on new product development performance as the criterion for future studies.

5.2.2 Practical suggestions

For business circle, the empirical result in this study can clarity the relation between product design and new product development performance as the criterion for companies with respect to related business. Since the corporate resources are limited, the integration analysis on product design and process management allows companies to select and distribute the resources. The practical suggestions are below:

(1) The empirical finding shows that companies which value product design more will have better new product development performance. The result can function as the criteria of positive design model. From the views of the companies, the value and involvement of companies in product design will not only leads to the profits, but also increase new product development performance.

(2) As to the relation between product design and process management, the empirical analysis demonstrates that companies will focus on different product design orientations. This study further analyzes the influence of the two on new product development performance and finds that most of companies in Taiwan are transformed from the man-

ufacturing companies. Thus, their product design is extended from engineering orientation, their original core ability. The study demonstrates that the integration between new product design and new product development process management will lead to better new product development performance.

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