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THE EFFECT OF DESIGNERS' PARTICIPATION ON INDUSTRIAL DESIGN PERFORMANCE IN THE PRODUCT DEVELOPMENT STAGE

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ABSTRACT

The study deals with the moderating effect of the designer's participation in the product development stage. We simplified the product development stage into three phases: 'Pre-Design,' 'Design,' and 'post-Design.' And the primary research method is Hierarchical regression analysis. The data selected quantitatively measured data from the "Industrial Design Statistical Survey". We conducted repeated analysis by varying the data set of major/medium, medium-sized, and small enterprises to see their differences. This study is an early-stage study that quantitatively measures the 'Design' process. Precedent studies on 'Industrial Design' are rarely quantitative due to difficulties in measuring the Qualitative character of industrial design.

INTRODUCTION

In 1984, Philip Kotler, a chair professor at the Kellogg School of Business, spoke about the value of industrial design. "The Value of industrial design as a 'potent/ variable is heralded in leading managerial textbooks and viewed widely as helping to provide a sustainable competitive advantage." Industrial design was recognized as a management factor that could create added value. However, nearly 25 years later, the area of 'design' is still abstract, and difficult to conduct quantitative research. In particular few studies quantitatively deal with industrial design and designers due to difficulties in data collection. Nevertheless, the participation of industrial designers in product development is essential and requires analysis. Therefore, this study presents the following questions.

- Is the effect of design investment on management performance affected by the level and scope of designer participation?
- Will the effect of design sourcing type on management performance be affected by the level and extent of designer participation?

This study examines the moderating effect of industrial designer participation in product development. We conducted a hierarchical regression analysis on 1,233 samples of manufacturing companies using design in the "Industrial Design Statistical Survey" through various industrial design-related variables.

LITERATURE

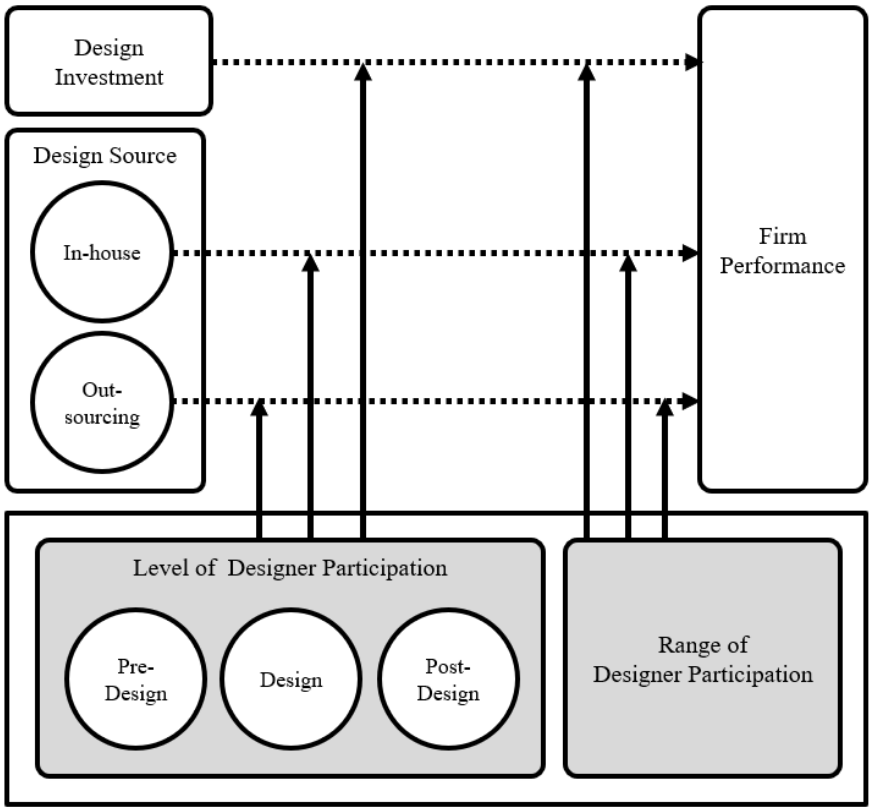
Product development process and design capabilities

The product development process is defined differently depending on the researcher.
Vink et al.(2008)classified the process into nine stages in the study of stakeholder contribution in the product development process, and Brockhoff (2003) classified it into seven stages in the study of customer participation. (Ahmadi and Wang, 1999) mentioned the industrial design process as an independent activity in the rocket development process and divided it into eight stages. The industrial design process belongs to the product development process and is generally integrated with the engineering design stage, but it is

a necessary process that requires separate knowledge and training. Eppinger and Ulrich (2015) emphasized that industrial design is a crucial task separate from engineering design, including concept development, product sketching, and prototype development.

In previous studies, design investment is a variable actively used concerning a company's design activities (Swink and Calantone, 2004; Hertenstein, Platt and Veryzer, 2005; Chiva and Alegre, 2009). R&D investment costs are disclosed on the financial statements and are frequently used, but design investment costs are not frequently used due to difficulties in collecting information. For this reason, existing studies collect respondents' judgments and opinions during surveys to estimate approximate design investment. We use design investment cost data. The design investment consists of financial figures for designer wages, purchase of design software and hardware, training costs for designers, and establishment of design facilities and laboratories. "Who does the design" is a significant decision-making issue in product development. In determining the design source of the product, whether to operate an Inhouse professional design department within the organization or entrust design to an external company can be an indicator of how a company establishes a strategy to utilize design (Maciver and O'Driscoll, 2010; Taha, Alli and Rashid, 2011; Czarnitzki and Thorwarth, 2012). The design source of a company can be classified into the outsourced or in-house design. Based on data reflecting the reality of Korean industrial design, we classified outsourcing targets into design-specialized firms and freelance designers (individuals). Moreover, product design outsourcing can be requested to design companies and freelancers simultaneously, depending on the project.

Figure 1: Research model



Operating profit excludes operating costs from sales and is suitable as a dependent variable for this study due to its low correlation with independent variables such as designer employment and design investment. Therefore we select operating profit as a dependent

variable (Chiva and Alegre, 2009; Fernández- Mesa *et al.*, 2013). Moreover, based on previous studies, 'R&D investment' and 'labor cost' are adopted as control variables (Swink and Calantone, 2004; Hertenstein, Platt and Veryzer, 2013).

Designer participation in product development

Supplier and consumer involvement in product development positively impact product performance (Ahire and Dreyfus, 2000; Mullens *et al.*, 2005; Vink, Imada and Zink, 2008). Moreover, studies show that the operation of design departments and the employment of designers positively affect corporate performance (Ahmadi and Wang, 1999; Krishnan and Ulrich, 2001; Page and Herr, 2002; Hertenstein, Platt and Veryzer, 2013). Based on these studies, industrial designers, as stakeholders, can have a similar impact on the product development process as suppliers or consumers.

Table 1: Product Development Process and Reclassification

3 phase process	**7 phases of Product Development Process**	**Weight***
Pre-design phase (Level 1)	Establishing Business Strategy	.18
	Market Research	.27
	Design Requirement and Ground rules	.45
Design phase (Level 2)	Design / Development Iterations	.61
	Production Engineering	.39
Post-design phase (Level 3)	Distribution / QC	.30
	Marketing Support	.24

This study defines the product development process in seven stages based on references, reclassifies it based on industrial design activities, and divides it into three levels: *pre-design*, *design*, and *post-design*. Using these levels, we analyse the 'designer participation level.'
The 'designer participation range' is a variable of how many stages designers participate in product development. Vink et al. (2008) defined the main responsible tasks for each product development stage and assigned job managers to derive the weight of their contribution level. According to research results, industrial designers are mainly involved in product concept development and prototype production among product development, but designers are also involved in the product development stage, production, and quality development stage. Referring to the Vink et al. (2008) study, we analysed the moderating effect of designer participation in the production process—the measurement indicators and units described in Table 2.

Table 2: Variable description

	Variables		**Measure / Unit**
Dependent Variables	Firm performance	Operating Profit	Log Operating profit
Independent Variables	Design Investment (DI)	Design Investment Rate	Design Investment / Sales
	Design Source	In-house Design (InD)	In-house design rate / % (0~100)
		Outsourcing to design firm (OFMD)	Outsourcing to design firm rate / % (0~100)
		Outsourcing to freelancer	Outsourcing to freelancer rate / %

	(OFLD)	(0~100)
Moderating Variables	Designer Participations Level (Level)	0 or 1 (binary)
	Designer Participation Range (PR)	$\sum$ Weights * Level
Control Variable	Employees	Log / Labor cost
	R&D Cost	Log / R&D cost

METHODS

Regression analysis is a method of determining how the value of the dependent variable changes according to the independent variable based on the magnitude of the effect of the independent variable (predicted variable) on the dependent variable (Cook and Weisberg, 1999). Regression analysis can be subdivided into simple and multiple regression analysis according to the number of independent variables and linear or non-linear regression analysis according to the relationship between independent and dependent variables.
Hierarchical regression, a type of multiple regression analysis, is mainly performed when the amount of additional variance in which a particular independent variable explains the dependent variable is the focus of the study (de Jong, 1999). Through this process, the degree of the explanatory power of the model considering the control effect is compared based on the model that does not consider the control effect, and the effect of the variable representing the control effect on the dependent variable is verified.
In addition, this study uses logistic regression analysis to verify industrial design activities that are difficult to explain quantitatively (Demirtas, Anagun and Koksal, 2009). Logistic regression is used to model relations between a categorical (binary, ordinal, nominal) dependent variable and some independent variables (continuous or categorical). According to this method, the effects of independent variables on the probability that the dependent variable belongs to a category are measured. In addition, data were classified and repeatedly analyzed to examine differences according to the company's size in verifying the moderating effect of designer participation. The data used 1233 manufacturing samples from the 2018 Industrial Design Statistics Survey.

RESULT

In the product development stage, the moderating effect of designers' participation level and the range of participation was verified. Repeated analysis was conducted with total samples (n=1233), small businesses (n=726), medium-sized companies (n=376), and large companies (n=131), and the differences were compared. Model V results from the moderating effect of the range of designer participation. It results from analyzing how many phases designers participate in the product development process. The initial results are vast, so a summary table is presented.

Design investment and the moderating effect of design participation

As a result of the analysis of Model II~IV, which reviewed the level of designer participation in all samples, it was found that designer participation in the Pre-design (Model II) and Post-design (Model IV) stages had no significant moderating effect. However, it was found that there was a significant moderating effect when the range of designer participation was extensive. These results differ from Maciver and O'Driscoll (2010) study that designers will lead the production process stage, and designers will be able to help with every step with multiplayer. For a more detailed analysis, samples are divided into small, medium, and large companies (including medium-sized companies) to examine what differences are shown by company size.
All the moderating effects related to designer participation were insignificant in the small business sample (n=726) and the medium-sized business sample (n=376). These results

are believed to have been challenging to extract results related to designer participation because the number of workers in SMEs was small, and many samples of companies still needed to hire separate designers. In other words, it was not statistically significant because designers had little participation in product development. The sample of large companies (n=131) has a positive moderating effect on the pre-design (II) and design (III) phases. In contrast, the post-design (IV) step is insignificant. Finally, when designers participated in various ranges of product development (V), it was found that there was a significant amount of influence. These results can be interpreted as large companies having their design capabilities and internal design personnel having more opportunities to participate in product development.

Table 3: Moderating effect of designer participation on the effect of design investment

Dependent variable \ Independent variable		I	II	III	IV	V
		Firm performance				
		Coefficient	Coefficient	Coefficient	Coefficient	Coefficient
Total n=1233	DI	0.015	0.005	-0.012	0.025	-0.034
	DI *Level1		0.013			
	DI *Level2			**0.048****		
	DI *Level3				-0.012	
	DI *PR					**0.058***
Small n=726	DI	-0.089**	-0.052	-0.117**	-0.062	-0.115*
	DI *Level1		-0.050			
	DI *Level2			0.043		
	DI *Level3				-0.036	
	DI *PR					0.031
Mid n=376	DI	-0.115**	-0.313*	-0.115**	-0.259	-0.148
	DI *Level1		0.210			
	DI *Level2			-0.018		
	DI *Level3				0.151	
	DI *PR					0.230
Large n=131	DI	0.015	-0.566**	-0.276	-0.042	-0.297
	DI *Level1		**0.615****			
	DI *Level2			**0.321***		
	DI *Level3				0.330	
	DI *PR					**0.334***

Design Source and the Moderating Effect of Design Participation

Table 4 summarizes the results of the moderating effect of in-house design and designer participation. As a result of the total sample (n=1233), it was found that the participation of the designer's Pre-Design(II) had a negative effect. In in-house design, participating in the product planning and specification determination stage corresponding to the product development planning stage can negatively impact performance. On the other hand, participation in the design (III) stage has a positive effect. Finally, participation in Post-Design (III) was insignificant. Finally, the moderating effect of the designer's range of participation (IV) is negative, indicating that designers' participation in various stages has a negative moderating effect. This effect differs from previous studies in that designers' active participation in product development has a positive effect. This result happened because the sample concentrated on small and medium-sized enterprises that do not have an in-house design.

Similar results were found for small businesses (n=726) and medium businesses (n=376). First, it was discovered that designers' participation in Pre-Design (II) had a negative moderating effect and that design (III) and post-Design (IV) participation had a significant positive effect. It means that it is more effective for designers of small and medium-sized companies to participate in product development and product design support than to participate in the planning stage. Finally, it was found that the range of designer participation (V) was insignificant. Interestingly, small, and medium-sized companies show similar tendencies. On the other hand, as a result of analysing the sample of large companies (n=131), it was found that the participation of pre-Design (II) and Design (III) had a significant positive effect, and Model V, in which designers participate in various stages, had a powerful moderating effect.

Table 4: Moderating effect of designer participation on the effect of In-house design

Dependent variable \ Independent variable		I	II	III	IV	V
		Firm performance				
		Coefficient	Coefficient	Coefficient	Coefficient	Coefficient
Total n=1233	InD	0.019	0.038*	0.016	0.038*	0.021
	InD*Level1		**-0.076***			
	InD*Level2			**0.011***		
	InD*Level3				-0.045	
	InD*PR					**-0.006***
Small n=726	InD	-0.039*	-0.018*	-0.044*	0.011	-0.025
	InD*Level1		**-0.099***			
	InD*Level2			**0.019***		
	InD*Level3				**0.130****	
	InD*PR					-0.040
Medium n=376	InD	-0.046*	0.023	-0.062*	0.021	-0.011
	InD*Level1		**-0.205***			
	InD*Level2			**0.062****		
	InD*Level3				**0.122***	
	InD*PR					-0.080
Large n=131	InD	-0.062	-0.082	-0.127*	-0.030	-0.323**
	InD*Level1		**0.049***			
	InD*Level2			**0.255***		
	InD*Level3				-0.041	
	InD*PR					**0.074*****

In the case of outsourcing design, only Table 5 and the Pre-Design (II) stage were significant when outsourcing the total sample (n=1233) design company, and the remaining results were insignificant. The small business sample (n=726) shows that the participation of 'freelancer designers' in Post-Design (IV) had a positive effect. Given that the Post-Design phase includes production, manufacturing, and design phases, support for designable design personnel who can be involved in the production and manufacturing phases can help with management performance. In the sample of medium-sized companies (n=376) refers, the participation of design companies (OFMD) had a positive effect in the Pre-Design (II) stage, and freelance designers (OFLD) had a positive effect on Design (III) and Post-Design (IV). Finally, the sample of large companies (n=131) indicated to have a negative effect when design-specialized companies participated in the Design (III) phase. In addition, the

participation of design companies in various stages of product development (V) also had a negative effect, and no significant results reveal concerning freelance designer outsourcing. In summary, large companies show more positive results in management performance than when developing products with in-house design, and medium and small companies can achieve more positive results when designing products through outsourcing design.

Table 5: Moderating effect of Designer Participation on the Effect of Outsourcing Design

Dependent variable \ Independent variable		I	II	III	IV	V
		Coefficient	Coefficient	Coefficient	Coefficient	Coefficient
Total n=1233	OFMD	-0.023	-0.046	-0.022	-0.036	-0.030
	OFLD	0.043*	0.035	0.045	0.025	0.036*
	OFMD *Level1		**0.044***			
	OFMD *Level2			-0.001		
	OFMD *Level3				0.015	
	OFMD *PR					0.010
	OFLD *Level1		0.018			
	OFLD *Level2			-0.004		
	OFLD *Level3				0.021	
	OFLD *PR					0.009
Small n=726	OFMD	0.029	0.007	0.033	0.008	0.001
	OFLD	0.065**	0.056*	0.075**	0.005	0.053*
	OFMD *Level1		0.042			
	OFMD *Level2			-0.017		
	OFMD *Level3				0.024	
	OFMD *PR					0.007
	OFLD *Level1		0.019			
	OFLD *Level2			-0.005		
	OFLD *Level3				**0.073***	
	OFLD *PR					0.015
Medium n=376	OFMD	0.042	-0.030	0.059	-0.015	0.010
	OFLD	0.046*	0.033	0.067*	-0.189	0.071
	OFMD *Level1		**0.131****			
	OFMD *Level2			-0.019		
	OFMD *Level3				0.062	
	OFMD *PR					-0.042
	OFLD *Level1		0.011			
	OFLD *Level2			**0.078***		
	OFLD *Level3				**0.238***	
	OFLD *PR					-0.045
Large n=131	OFMD	0.054	0.119	0.170**	0.140*	0.279**
	OFLD	0.094	0.288	0.103*	0.246	0.060
	OFMD *Level1		-0.147			
	OFMD *Level2			**-0.274****		
	OFMD *Level3				-0.113	
	OFMD *PR					**-0.375****
	OFLD *Level1		0.054			
	OFLD *Level2			0.061		

OFLD *Level3	-0.152	
OFLD *PR		-0.068

DISCUSSION

This study examined the moderating effect of designer participation in the product development process on the performance of corporate design activities. Hierarchical regression analysis was performed on 1233 effective samples using industrial design statistics survey data.

As a result of the analysis reveals that if designers participate in the appropriate stage of the product development process, the impact of design investment on corporate performance increases. We verified that having professionals who can understand and develop products in the design stage (concept design, prototyping) appears the same at all corporate sizes. However, the level of designer participation in the pre-design stage of the production process was found to be affected by the size of the company or the design entity (outsourcing, in-house). In the case of large companies, the pre-design stage leads to positive results regardless of all control effects, and in particular, in the case of in-house design, it has a more substantial moderating effect. In the case of small businesses, it exhibits that putting designers in early stages could have a negative impact. In the case of outsourcing design through a design company, the participation of designers in all stages of design has a substantial positive control effect, and in the case of outsourcing, the analysis of the total sample has been verified to have a positive control effect. However, when it comes to in-house design, it was found that the participation of designers in all stages of design has a negative effect on both small and medium-sized companies.

When small and medium-sized enterprises implement an in-house design, it is significant to put designers in the design and post-design stages. It depicts that putting designers in all design stages had a negative effect. On the other hand, large companies have a positive moderating effect by putting designers into the design stage during in-house design. In other words, the practical stages designers participate in differ depending on the company's size. In addition, for medium-sized companies, designer participation in all phases employing outsourcing design-specialized firms was found to have a solid positive control effect. Furthermore, it confirmed that the samples of small and large companies were insignificant, and there was a difference according to the company size.

In the case of multiple stages of in-house design by large companies, it shows that the participation of designers in multiple stages had a powerful positive moderating effect ($P<0.01$). On the other hand, in the case of SMEs and small businesses, it was found that both in-house design and outsourcing design were insignificant or had a negative effect.

IMPLICATIONS

This study has several implications. First, the study is an early-stage study that quantitatively measures the 'Design' process. Precedent studies on 'Industrial Design' are rarely quantitative due to difficulties in measuring the Qualitative character of industrial design. Unlike previous studies, it has theoretical value because it attempted to measure the quantitative effect of industrial design on corporate performance. Second, the study provides reference materials related to the use of industrial design for small and medium-sized enterprises. Small and medium-sized enterprises are easier to imitate large companies' products than to develop original designs and have low awareness of design value (Korea Institute of Design Promotion, 2013). The low need for the design of small and medium-sized companies naturally consists of the low employment of designers (Choi, 2017), and the employment insecurity of designers leads to a vicious circle that leads to low-level design or design copy. Compared to the United Kingdom, the United States, and Europe, Korea does not consider design as industrial property yet. Designers are a vital, irreplaceable resource in the manufacturing industry (van Aken, 2005), and SMEs do not

seem to realize this fact. When designers participate in the product development stage, they can improve development efficiency and consequently positively impact corporate performance (Eppinger and Ulrich, 2015). Studies that analysed several large companies argue that the value of design positively affects a company's financial performance (Hertenstein, Platt and Veryzer, 2005; Chiva and Alegre, 2009). This study discussed "when designers should be deployed in the product development stage" and at what scale companies should consider hiring designers to emphasize the need for designer employment. Based on the results, suggestions that can be referenced for designer participation or design resource input at the product development process stage according to the company's size are summarized as follows.

Table 6: Suggestions for Designer Participation

	Participation Level (Phase)	Participation Range
Large company	***Pre-Design*** *(Design Requirement)* ***Design*** *(Concept Design, Prototype)*	Expand
Mid-size company	Pre-Design (Outsourcing Design Firm) ***Design*** *(Concept Design, Prototype)* Post-Design (engineering, Production, QM)	-
Small company	Design (Concept Design, Prototype) ***Post-Design*** *(engineering, Production, QM)*	-

This study discussed "when designers should be put in the product development stage" and "when companies should consider hiring designers" to emphasize the need for designer employment. Based on the results, Table 6 summarizes the suggestions regarding the designer input strategy according to the size of the company.

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