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Understanding Designer Engagement in the Product Development Process: Evidence from Japanese Manufacturing Companies

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ABSTRACT

The role of designers in the product development process (PDP) has become increasingly important. However, there is still insufficient empirical evidence regarding the actual engagement of designers in the PDP and their relationship with product development performance and market conditions. In this study, through quantitative surveys and analysis targeting Japanese manufacturing companies, we clarified how designers engage in each stage of the PDP and how their engagement is related to product development performance and market conditions. The analysis results revealed significant differences in how designers engage in the PDP between companies. Particularly, notable differences were observed in how designers contribute to screening and evaluation of product ideas, product concepts, and prototypes. Furthermore, it became evident that companies consistently engaging designers throughout the entire PDP achieve high design performance and market performance. On the other hand, in terms of development efficiency performance, consistent and high-degree designer engagement throughout the PDP was not shown to have a pronounced effect. Finally, the analysis results indicated that how designers engage in the PDP is closely related to design intensity rather than technological or competitive intensity in the market.

Keywords: Design Management, Designer Engagement, Product Development Process

INTRODUCTION

In recent years, design has been recognized as a contributor to brand building, product innovation, and corporate performance (Guo, 2010). The scope of design has expanded beyond the aesthetics of products and now encompasses a wide range of elements, including the product–user interface, the user's experience with the product, and even the environment in which the product is used (Chiva & Alegre, 2009). When design is considered in this broader context, it becomes closely related to various stages of the product development process (PDP), making the designer's engagement in the PDP crucial for overall performance (Chiva-Gomez, 2004). Previous studies have observed that consistent engagement of designers from the early stages of the PDP has a positive impact on performance (Goffin & Micheli, 2010; Roper et al., 2016). Some studies have also highlighted the usefulness of designers in the PDP as coordinators between functions and even project leaders (e.g., Perks et al., 2005; Goffin & Micheli, 2010). However, another perspective is that the role of designers in product development activities remains as supporter for other functions (Marsili & Salter, 2006). This has led to significant attention focused on the patterns of designer engagement in the PDP.

The aim of this study is to quantitatively clarify the reality of designer engagement at various stages of the PDP and how it relates to product development performance and the market environment. Specifically, through quantitative surveys and analysis targeting Japanese manufacturing companies, this study seeks to reveal how designers engage in each stage of the PDP, how their engagement relates to product development performance and market environment.

This study intents to make academic contributions primarily in two areas related to existing studies on the engagement of designers in the PDP.

As the first area, the study intents to quantitatively clarify the reality of designer engagement in the PDP and its effects on product development performance. While the previous literature has highlighted the importance of designer engagement in the PDP, much of it has comprised conceptual discussions or qualitative studies lacking sufficient quantitative verification. Therefore, the degree of designer engagement in each stage of the PDP and how their engagement relates to product development performance and the market environment remain insufficiently revealed.

As the second area, this study focuses on designer engagement in screening and evaluation at each stage of the PDP, aiming to provide a more detailed and refined understanding of the reality and effectiveness of designer engagement. Existing studies have often overlooked the degree of designer engagement in decision-making process, including screening and evaluation, at each stage of the PDP. In contrast, this study conducts analyses that takes into account not only whether designers engage in each stage of the PDP but also to what extent they engage and how they engage in the decision-making process at each stage.

1. REVIEW OF PREVIOUS STUDIES

1.1. Scope of design in product development activities

In existing design management studies, design has primarily been considered as both an outcome and a process (Talke et al., 2009). Talke et al. (2009) and Rubera (2015) have argued that design can provide aesthetic and emotional value to users and build a corporate brand, primarily through the attractive appearance of products. Additionally, Luchs & Swan (2011) have viewed design as comprising elements and targets including forms, functions, and their integration, which captures the process of design from idea generation to commercialization. Chiva & Alegre (2009) have recognized the importance of design as encompassing elements such as functionality, appearance, and usability, and in addition to the product's functionality and appearance, they have emphasized design's role in creating interfaces between products and users and creating the user experience. In recent years, design has expanded its scope, evolving from merely the creation of the appearance of products to encompass processes that generate product ideas, concepts, product–user interfaces, and user experiences. Consequently, the role and engagement of designers in the PDP have gained increased recognition.

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1.2. How designers engage in the PDP

Existing studies have highlighted that the patterns and timing of designers' engagement in the PDP can impact the utilization of their abilities and the performance they achieve. For example,

Kyffin & Gardien (2009) and Goffin & Micheli (2010) showed that when designers are engaged from the early stages of market research in the PDP, they can interpret user needs uniquely, generate innovative ideas effectively, and successfully reduce development costs. Conversely, some studies have focused on engaging designers in the research and technology development stages. Moultrie (2015), for instance, argued that engaging designers in the early stages of R&D makes it easier to assess the practicality of technology and align research directions. There have also been studies reporting the effectiveness of continuously engaging designers throughout the entire PDP. Roper et al. (2016) pointed out, based on quantitative analysis of companies in Ireland, that as designer engagement becomes more extensive and continuous, product development performance improves. In summary, existing studies have suggested that the continuous engagement of designers in the PDP can enhance product development performance. Behind these claims lies the expectation that design, with its unique approach distinct from marketing and engineering, promotes the development of products with high levels of innovation (Kyffin and Gardien, 2009). Additionally, engaging designers consistently from the early stages of the PDP is expected to reduce late-stage modifications and lower development costs.

1.3. Market environment factors

Generally, design management is influenced by the market environment that companies face (Luchs & Swan, 2011). Therefore, when considering how designers engage in the PDP, including their roles, it is essential to take into account the relationship with the market environment that companies face.

Candi & Saemundsson (2011) have suggested that in situations where the technology is mature, design providing usability and symbolic value to products complements a lack of technological innovation, prevents cost competition, and contributes to product differentiation. Furthermore, Chan et al. (2018) stated that as a product life cycle progresses and the product technology and functionality mature, the importance of design in terms of the appearance of the product becomes more prominent. However, Talke et al. (2009) emphasized that design is important throughout the product life cycle.

Perks et al. (2005) argued that the extent of designer engagement in the PDP expands as market competition intensifies. Verganti (2009) suggested that changes in the competitive environment have led to a shift in the importance of designers who excel at transforming product meanings in response to such changes, making their role crucial. Candi & Saemundsson (2011) also contended that as commoditization progresses, increasing price competition in the market environment enhances the impact of design on performance. Therefore, the escalation of competition in mature markets seems to influence the roles and engagement of designers in product development activities.

Ulrich & Eppinger (2019) demonstrated that in industries where design is recognized as strategically important, designers are engaged in the early stages of the PDP. Gemser & Leenders (2001) suggested that the degree to which design is leveraged in an industry influences how designers are utilized. Additionally, some studies have indicated that consumer attitudes and sensitivities to design are closely related to how design is utilized. For example, Mugge & Dahl (2013) argued that the acceptance of innovative design in the market depends on consumers' sensitivity to design. Therefore, it is evident from existing studies that

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the degree to which design is valued in an industry and customers' attitudes and sensitivities to design can influence how designers are utilized in product development activities.

1.4. Issues in previous studies and positioning of this study

As previously discussed, existing studies have increasingly recognized the growing scope of design in product development activities and its significant impact on product development performance. Moreover, studies have hinted at the relationship between how designers engage in the PDP and the contextual factors of the market environment. However, existing studies have some limitations that this study aims addressing in order to fill in gaps in the literature.

The first issue is the scarcity of quantitative and empirical research. While some existing studies have highlighted the utility of engaging designers consistently from the early stages of the PDP, much of that research was qualitative and relied on conceptual discussions.

The second issue is that the designer engagement in the PDP was oversimplified in those studies. Their primary focus was on confirming whether designers were engaged in the key stages of the PDP and did not adequately capture the extent of designer engagement in each of the different stages. Furthermore, the studies gave insufficient consideration to designer engagement in decision-making at each stage of the PDP.

The third issue is that the relationship between the designer engagement in the PDP and the market environment faced by the product development organization has not been adequately considered. While existing studies have emphasized that how designers engage in the PDP has a significant impact on product development performance, they often failed to adequately consider the context in which the engagement functions.

This study aims to address the aforementioned issues by quantitatively revealing how designer engagement in a company's PDP is related to both product development performance and the market environment.

2. SURVEY OVERVIEW AND ANALYTICAL METHODS

2.1. Survey overview

In this study, we conducted a survey entitled "Survey on Corporate Design Activities" using a questionnaire mailed to manufacturing companies in Japan designed to address the research objectives. In the sampling process, we selected 1,991 companies in the Japanese manufacturing industry that were believed to require product design and had in-house designers. In October 2022, the questionnaire was sent to the design managers or persons responsible for design at each company, requesting their responses. We received responses from 405 companies. Three companies that reported not having in-house designers were excluded from the analysis. Subsequently, we analyzed a total of 401 response questionnaires without missing values resulting in an effective response rate of 20.2%.

The industries represented by the responding companies include automobiles (cars and motorcycles) (2.7%), automotive-related equipment and parts (3.7%), transportation equipment (2.7%), household electrical appliances (8.2%), industrial electrical equipment (7.0%), machinery (13.2%), precision equipment (6.5%), industrial and business equipment (2.7%), medical equipment and instruments (2.0%), stationery and office supplies (3.5%),

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furniture, interior, and equipment (5.0%), daily goods and lifestyle products (11.5%), sports and outdoor equipment (2.7%), housing (4.5%), housing-related equipment (11.0%), plastic products and components (5.2%), metal products (2.2%), and paper and wood processing products (5.5%). In the case of companies engaged in multiple businesses, we asked them to select the primary industry sector when responding and provide their answers with a focus on that specific business.

The questionnaire items primarily consisted of questions related to designer engagement in various stages of the PDP, questions about product development performance, and questions about the market environment that the company (or its business units) faces.

During the development of the questionnaire, after setting the questionnaire items, we conducted interviews with a total of five individuals: two designers from a general electronics manufacturer, one designer from an automotive manufacturer, one marketer, and one designer from a household goods and furniture manufacturer. We collected their opinions on each questionnaire item and its content and modified the questionnaire based on insights obtained from those opinions.

2.2. Overview of date and measurement scales

To comprehensively capture the stages of the PDP, this study followed the model proposed by Millson & Wilemon (2002) and included the following eight stages: research and technology development, market research, analysis and targeting, product idea generation, product concept development, prototype development, product structure and specification design, and test marketing. Additionally, drawing inspiration from Oswald et al. (2012), we also included the following three stages: screening and evaluation of product ideas, screening and evaluation of product concepts, and user testing and evaluation of prototypes. To assess the degree of engagement at each stage, we used a 7-point Likert scale for each item.

Generally, design management seeks to create design outputs that enable fundamental differentiation. To achieve differentiation from competing products, it is essential to achieve high levels of innovation in the design outputs in terms of product appearance (Talke et al., 2009). Thus, we set questions based on Gemser & Leenders (2001) and Calantone et al. (2006) to assess the level of innovation compared to existing design outputs in the market, and questions following Song & Swink (2009) to evaluate whether design contributes to product innovation and provides new value to customers.

Furthermore, such design outputs are expected to contribute to corporate performance, such as increased sales, profits, and market share (Guo, 2010). Design outputs also enhance customer loyalty and contribute positively to the corporate brand image (Townsend et al., 2013), since design as a visual component plays a crucial role in building and enhancing the image of a brand. Consequently, following Gemser & Leenders (2001) and Micheli & Gemser (2016), we set questions to assess whether design contributes to business profitability, product sales, customer loyalty, and brand image building.

In existing product development studies, achieving product integration, which consists of external integration fitting products to the market and internal integration harmonizing various functions engaged in development, was emphasized as an effective organizational pattern for product development activities (Clark & Fujimoto, 1991). In the context of design management, creating outstanding design outputs accepted by the market represents external

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integration, while efficiently coordinating and integrating design with other functions throughout the PDP to enhance its efficiency and productivity represents internal integration. Therefore, we set questions to assess the achievement of development efficiency and productivity, following Millson & Wilemon (2002).

Based on the above considerations, this study measured product development performance in three dimensions: design performance, market performance, and development efficiency performance. Generally, subjective evaluations of product development performance data obtained through questionnaire surveys are strongly correlated with objective data such as financial indicators and market share (Wall et al., 2004). Hence, following Gemser & Leenders (2001) and Micheli & Gemser (2016), we measured each performance dimension through subjective evaluations by representatives involved in a company's design activities, using a 7-point Likert scale for all items.

Lastly, regarding the business environment faced by companies, we focused on three aspects—technological intensity, competitive intensity, and design intensity in the market—drawing from existing studies as follows: we designed the questions related to technological intensity and competitive intensity based on Jaworski and Kohli (1993), while the questions regarding design intensity were originally developed with reference to Srinivasan and Lilien (2018) and Gemser and Leenders (2001). All of these items were measured using a 7-point Likert scale, and confirmatory factor analysis was performed.

Table 1: Factor Analysis Results.

Factors	Items	Ave	S.D	Factor Loading	Cronbach's α	CR	AVE
Design Performance	It is a design that provides customers with new value and impressions.	4.77	1.55	0.89	0.95	0.96	0.79
	The product's design is something that has not been seen in the conventional market.	4.52	1.63	0.88			
	The product's design is pioneering compared to competitors.	4.47	1.64	0.88			
	The appearance of the product is significantly differentiated compared to competitors.	4.81	1.51	0.87			
	The product's appearance stands out in the market.	4.52	1.48	0.90			
	The product possesses visual characteristics that are distinct from those of competitors.	4.74	1.52	0.90			
Market Performance	It has achieved higher profitability compared to the past.	4.31	1.45	0.79	0.78	0.86	0.60
	It has reached the target sales of product.	4.73	1.36	0.81			
	It has realized high customer satisfaction.	5.14	1.05	0.78			
	It contributes to the enhancement of the corporate brand image.	5.30	1.18	0.72			
Development Efficiency Performance	It is achieving the targeted product development timeline.	4.23	1.53	0.81	0.86	0.90	0.70
	Product development activities are being conducted efficiently as a whole.	4.06	1.43	0.83			
	The time from initiation of development to market launch has been shortened.	4.00	1.54	0.85			
	The progress speed of product development activities is improving.	4.16	1.46	0.87			
Technological Intensity	In the industry, new products are incorporating new features.	4.66	1.34	0.90	0.77	0.90	0.81
	In the industry, pioneering product features are considered to be a crucial factor in building a competitive advantage.	5.30	1.29	0.90			
Competitive Intensity	Competitors frequently introduce new products.	4.97	1.11	0.86	0.77	0.87	0.69
	Price competition with competitors is not the sole factor but is an important one.	5.82	1.13	0.80			
	Among companies in the industry, product imitation and emulation are common practices.	5.45	1.14	0.83			
Design Intensity	Companies in the industry prioritize design as a source of competitive advantage.	4.66	1.59	0.83	0.86	0.91	0.71
	In the industry, new designs are frequently introduced.	3.84	1.61	0.81			
	The level of customer demand for design is high.	4.80	1.48	0.87			
	Product design is emphasized in customers' purchasing decisions.	4.77	1.61	0.86			

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Table 2: Pearson's Correlation Coefficient.

Items		1		2		3		4		5		6
1	Design Performance	1.00										
2	Market Performance	0.43	**	1.00								
3	Development Efficiency Performance	0.22	**	0.37	**	1.00						
4	Technological Intensity	0.12	*	0.08		0.16	**	1.00				
5	Competitive Intensity	-0.09		0.02		0.09		0.29	**	1.00		
6	Design Intensity	0.31	**	0.16	**	0.16	**	0.32	**	0.29	**	1.00

** $p < 0.01$, * $p < 0.05$

The results of the confirmatory factor analysis are presented in Table 1. Since the data collected in this study came from the same respondents, concerns regarding common method bias were addressed. Following Podsakoff et al. (2003), efforts were made to separate responses between measurement scales physically and psychologically by using a lengthy questionnaire to reduce bias and enhance the quality of each measurement scale. Additionally, following Podsakoff & Organ (1986), the presence of common method bias was examined using Harman's single-factor test. Exploratory factor analysis (maximum likelihood method, no rotation) was conducted with an eigenvalue extraction condition of greater than 1. Since the first factor accounted for only 26.27% of the variance, it was determined that common method bias was not a significant issue.

Next, following the procedure proposed by Hair et al. (2017), the validity of the measurement scales was confirmed. The Cronbach's α coefficients for each construct ranged from 0.77 to 0.95, surpassing the common criterion of 0.70 (Nunnally, 1978). Additionally, the composite reliability (CR) ranged from 0.86 to 0.96, exceeding the common criterion of 0.70 (Fornell & Larcker, 1981). Furthermore, the average variance extracted (AVE) ranged from 0.60 to 0.81, surpassing the common criterion of 0.50 (Fornell & Larcker, 1981). Moreover, the squared correlations between all constructs were lower than the AVE for each construct, confirming convergent and discriminant validity.

2.3. Analysis methods

In this study, we conducted the analysis following the steps outlined below.

Firstly, we performed a two-step cluster analysis (Everitt, 1980) on the data regarding the engagement of designers in the PDP in order to understand the actual situation of how companies conduct such engagement. Additionally, with the aim of exploratively classifying the data, we compared the categorized groups to analyze the relationship between the engagement of designers in the PDP, product development performance, and market environmental factors. Through cluster analysis, this study aimed to classify companies into layers where the patterns of designer engagement in various stages of the PDP are similar. After conducting such a classification, we performed comparative analysis on these layers to analyze how the patterns of designer engagement relate to product development performance and market environmental factors.

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In the cluster analysis, we used the AIC criterion to select the number of clusters, resulting in three clusters. The silhouette index, indicating cluster quality, showed an acceptable level. Next, within the groups classified by cluster analysis, we conducted comparative analysis regarding product development performance and the market environment that companies (or business units) face. Since the data for each variable were ordinal-scale data on a 7-point scale, we used the Kruskal-Wallis test, a non-parametric method for conducting comparisons among three or more groups, for discrete data. When significant differences were observed among items, we performed multiple comparisons using the Dunn-Bonferroni method.

3. ANLYSIS RESULTS

Looking at the overall average degree of designer engagement in the various stages of the PDP, from research and technical development to prototype user testing and evaluation, the median value exceeds 4 on the 7-point scale, indicating a certain degree of designer engagement. On the other hand, the implementation of test marketing and the planning of production lines fall below 4, indicating a lower degree of designer engagement in these stages (Figures 1).

In this study, we performed hypothesis testing on the differences in mean values of designer engagement across the three groups classified by cluster analysis, which we designated as "High-Engagement Group (n = 91)," "Moderate-Engagement Group (n = 198)," and "Low-Engagement Group (n = 112)" (Figures 2). The hypothesis tests for differences in mean values between the three groups showed a significant difference at the 1% level for all items except for planning the production line. The High-Engagement Group consistently exhibits a high degree of designer engagement compared to the other groups. This group not only has a high degree of engagement in generating product ideas, defining product concepts, and developing prototypes but also consistently exhibits high engagement in screening and evaluating these stages, suggesting a consistently high Group, while designers are relatively highly engaged in generating product ideas and defining product concepts, their engagement in the screening and evaluation of these stages is comparatively low. Lastly, the Low-Engagement Group demonstrates a consistently low degree of designer engagement throughout the PDP. This group has lower engagement in screening and evaluation than in generating product idea, product concept and prototype similar to that of the Moderate-Engagement Group.

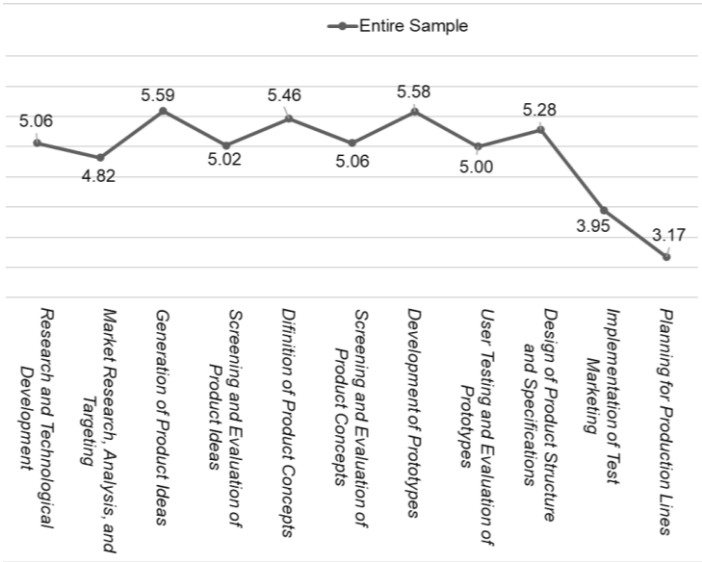

Figure 1. Designer Engagement in PDP: Entire Average.

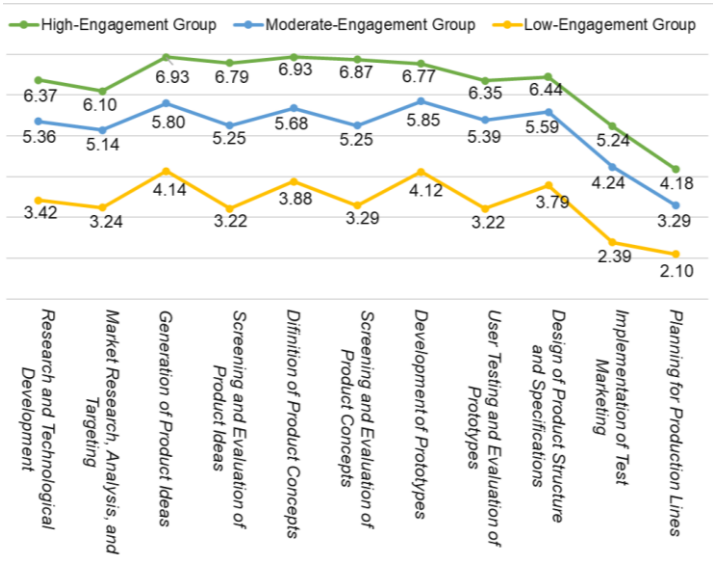

Figure 2. Designer Engagement in PDP: Between-Group Comparison.

These results indicate that there are differences in how designers engage in the PDP across companies. Specifically, there are significant variations in the degree of engagement in decision-making processes, such as generating product ideas, defining product concepts, and screening and evaluating these stages.

Next, we compared product development performance between the three groups. In terms of design performance, the rankings from highest to lowest were as follows: High-Engagement Group (0.36), Moderate-Engagement Group (0.02), and Low-Engagement Group (-0.35). There were significant differences between the groups. Regarding market performance, the rankings from highest to lowest were High-Engagement Group (0.33), Moderate-Engagement Group (0.05), and Low-Engagement Group (-0.35), and significant differences were again observed between the groups. Finally, in terms of development efficiency performance, the rankings from highest to lowest were Moderate-Engagement Group (0.073), High-Engagement Group (0.070), and Low-Engagement Group (-0.21). Notably, the differences between the Moderate-Engagement Group and Low-Engagement Group were significant at the 10% level, whereas differences between the other pairs of groups were not statistically significant.

Finally, we compared three factors—technological intensity, competitive intensity, and design intensity—in the market between the three groups. In terms of technological intensity, the rankings from highest to lowest were High-Engagement Group (0.04), Moderate-Engagement Group (0.03), and Low-Engagement Group (-0.11), but there were no significant differences between the three groups. Regarding competitive intensity, the rankings from highest to lowest were High-Engagement Group (0.08), Moderate-Engagement Group (-0.02), and Low-Engagement Group (-0.04), again with no significant differences. Concerning design intensity, however, the rankings from highest to lowest were High-Engagement Group (0.32), Moderate-Engagement Group (0.06), and Low-Engagement Group (-0.36), and there were significant differences observed between the groups, indicating that the differences in design intensity between the groups were pronounced compared to those of technological and market intensity.

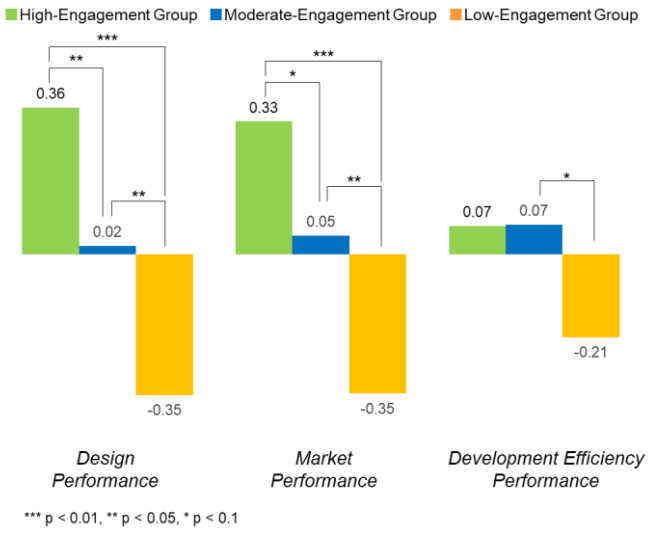

Figure 3. Between-group comparison pf product development performance.

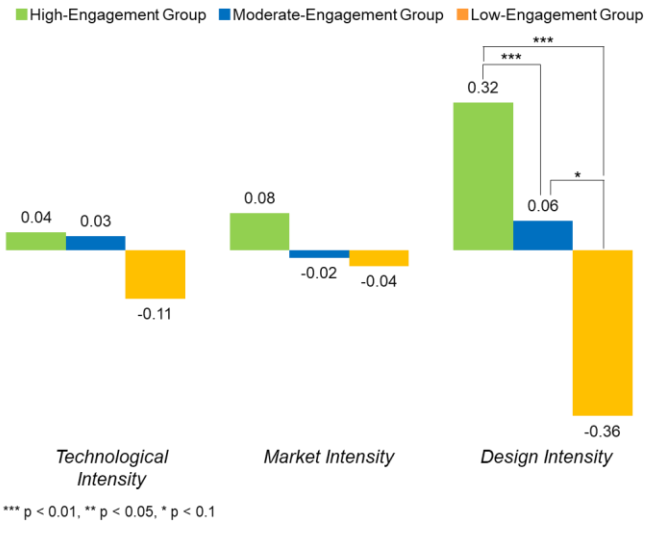

Figure 4. Between-group comparison of market environment

4. DISCUSSION

The objective of this study was to reveal the actual engagement of designers in the PDP in Japanese manufacturing companies and to understand their relationship with product development performance and the market environment. As a result, we obtained several key findings.

The first finding is that companies that consistently engage designers throughout the entire PDP achieve high design and market performance. Roper et al. (2016) argued that when designers are engaged in a wider range of activities, design is inherently recognized as a social process. Moreover, Verganti (2009) suggested that continuous designer engagement in the PDP helps generate new product meanings and languages that have the potential to spread in society and promote innovative ideas. Thus, the results of this study suggest that when designers consistently engage in every stage of the PDP, they effectively utilize design-specific approaches. By deeply engaging in these decision-making processes, designers prevent modifications to product concepts and prototypes created by designers based on the intentions of other departments. This, in turn, encourages the creation of design outputs with a high level of innovation, contributing to corporate performance and brand building.

The second finding is that a consistently high degree of designer engagement throughout the PDP does not yield significant improvements in development efficiency performance. Existing studies have suggested that engaging designers consistently from the early stages of the PDP can enhance development efficiency. However, analysis results of this study did not support these claims. One possible explanation for this difference in results is that engaging designers throughout the entire PDP may incur various costs.

This is firstly because engaging designers in every stage of the PDP might increase the costs associated with coordinating with other functions. What designers pursue may not necessarily align with what other functions such as engineering, production, and marketing pursue (Song & Swink, 2009). Therefore, when designers engage in all stages, conflicts may more frequently arise in decisions related to product concepts, prototypes, and product structures. This could result in increasing the costs associated with resolving conflicts. Secondly, a design-specific approach to the PDP may increase uncertainty. Rubera (2015) and Micheli & Gemser (2016) pointed out that developing innovative designs requires significant cognitive effort from consumers and may involve costs. In other words, developing innovative designs may attract consumer attention, but uncertainty may remain in terms of consumer acceptance. To mitigate this uncertainty, careful testing and screening/evaluation of product concepts and prototypes may be necessary. The analysis results of this study suggest that while consistently high-degree designer engagement throughout the PDP enhances design and market performance, it may also lead to higher development costs, potentially sacrificing development efficiency.

The third finding is that how designers engage in the PDP may be closely related to the design-related market environment that the companies face. Existing studies have suggested that how companies utilize designers may be related to the technological and competitive environment in the market. In contrast, this study's analysis results revealed no significant differences between the three groups with respect to technological and competitive intensity in the market. However, significant differences were observed between the groups in terms of design intensity in the market. Design intensity, in this context, refers to the extent to which design is

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valued in the industry or market, the level of customer requirements related to design, and the importance of design in purchasing decisions.

Many studies (e.g., Candi & Saemundsson, 2011; Rubera, 2015) have primarily focused on Western companies and have indicated that design is emphasized in situations with high technological maturity and intense competition. In the case of Japanese companies, it has been pointed out that the internal status of designers is relatively low. Therefore, changes in the competitive environment resulting from technological maturity may not necessarily directly lead to enhanced designer engagement in the PDP. Considering that the analysis data are based on the subjective assessments of responding companies, we should note that companies that increase designer engagement in the PDP may perceive a high degree of design intensity in their industry or market and may be emphasizing and strengthening the use of designers in response to the design-related environment.

5. ACADEMIC CONTRIBUTIONS OF THIS STUDY AND FUTURE CHALLENGES

The academic contributions of this study primarily comprise the three points.

The first contribution is that we quantitatively revealed the reality of designer engagement in the PDP and its effects. Many existing studies on designer engagement in the PDP have been based on conceptual discussions or qualitative surveys and analyses. In contrast, this study used surveys and analysis targeting Japanese manufacturing companies to quantitatively disclose the actual engagement of designers in the PDP and demonstrated how different patterns of engagement relate quantitatively to product development performance and the market environment.

The second contribution is that we provided a more refined understanding of the effects of designer engagement by separately measuring their contributions to generating product ideas, defining product concepts, developing prototypes, and their engagement in screening and evaluation at these stages. Existing studies discussing the effects of designer engagement in the PDP have typically focused on whether designers engage in each stage, with little consideration of the degree of engagement or their participation in screening and evaluation. Therefore, these studies might have overestimated the effects of designer engagement. In contrast, this study showed that companies where designers highly engage in critical stages of decision-making tend to have high design and market performance. To gain a more accurate understanding of the effects of designer engagement, it is necessary to consider not only whether they engage but also the degree of engagement in decision-making processes.

The third contribution is that we demonstrated differences in the effects of designer engagement between performance categories. Existing studies have explored various performance indicators related to design management, such as the quality of design output, financial outcomes in the market, customer evaluations, and the efficiency of product development activities. However, few studies have simultaneously analyzed these different performance indicators. In this study, we simultaneously analyzed how the patterns of designer engagement affect three performance categories: design output, market, and development efficiency.

However, this study has its limitations and unresolved challenges. Firstly, although we have revealed the relationship between designer engagement in the PDP and product development

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performance, the detailed mechanisms and logic are not fully explained. Further qualitative investigation and analysis are needed to determine what logic and mechanism causes the analytical results of this study. Secondly, although this study considered the external context of the market environment, it did not take into account internal contextual factors, such as organizational factors. To gain a deeper understanding of how design management affects the utilization of designers and product development performance, analysis that considers organizational contexts such as company size, strategy, organizational structure, top management supports, and coordination with other functions is necessary. These issues should be addressed in future research.

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