Integration of marketing domain and R&D domain in NPD design process

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Abstract

Purpose – To solve the trade-offs between marketing and R&D domains and to minimize information loss in new product development (NPD), this study proposes an integrated design process as a new solution to the interface system between the two domains.

Design/methodology/approach – House of Quality integrated with multivariate statistical analysis is used for determining important design features. These design features are used as parameters for conjoint analysis and Taguchi method, and then the results of analyses are compared. Sequential application of conjoint analysis and Taguchi method, depending on the differences in utilities and signal to noise ratios, is applied for the integrated design process. An automotive interior design is illustrated for the validation of the integrated design process.

Findings – The integrated design process determines a point of compromise between the optimums of conjoint analysis and Taguchi method. Sequential application of two methods ensures full utilization of both methods and no loss of information.

Research limitations/implications – More illustrations on NPD are needed to verify the proposed process.

Practical implications – The design process suggested in this study can be used for process innovation in six sigma approach and be integrated with value chain intelligently. This study proposes the strategic guideline of the integrated design process for enterprises.

Originality/value – The integrated design process suggests the solution for the trade-offs between marketing domain that pursues the utility of product and R&D domain that emphasizes robustness of product quality. This integrated design process will give enterprises competitive advantages in NPD.

Keywords Product development, Marketing, Conjoint analysis, Taguchi methods, Integration, Research and development

Paper type Research paper

Introduction

There are two kinds of approaches, named as process and domain view, in new product development (NPD). The process view looks at the activities of domains simultaneously in development process, while the domain view investigates the activities of domains independently (Chakravarty, 2001). With the recent trend of the process view, the barrier between domains and departments has been broken down in NPD (Song *et al.*, 1997). In accordance with the trend, it becomes necessary for product developers to mutually understand all domains related to NPD in an enterprise. Thus, the interface system which can reduce the conflict of gain and loss in the two domains is becoming an increasingly important research area.

Specifically, in NPD, the marketing-R&D interface coordination becomes important because the perspectives of R&D and marketing should substantially overlap each

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other as companies move further along the route towards the market orientation (Millman, 1982). Therefore, numerous studies have explored this marketing-R&D interface and its role in the NPD process to help better understand the researchable issues relating to integrating mechanisms for the marketing and R&D (Griffin and Hauser, 1996). The meaning of integration is making applications work together in the different domain by passing information through some forms of the interface systems (Gulledge, 2006), and the interface system is similar to the agent technology, which can facilitate a collaborative product design and make the different domain contribute to each other stages (Cheng *et al.*, 2006; Huang *et al.*, 2006).

Although there are many studies and propositions about the conceptual framework to integrate the marketing and R&D, research on the substantial integration of the NPD methodology itself is still in its early stage. So far, the conjoint analysis in marketing or the Taguchi method in R&D has been studied in each domain independently. Furthermore, previous research on the integrated NPD methodology has focused on the QFD, which is known to be techniques frequently used to link the two domains in NPD (Chakravarty, 2001; Cristiano *et al.*, 2000), and these studies have dealt with the QFD integrated into conjoint analysis or the QFD integrated into Taguchi method (Park *et al.*, 2005; Katz, 2004; Pullman *et al.*, 2002; Terninko, 1997, 1992; Chu, 1996; Gustafsson, 1993). Therfore, there have been only few studies trying to compare the conjoint analysis and Taguchi method directly and to present an optimized linkage system in interface between the two domains. Considering the foregoing background, the main purpose of this study is to compare the results of the conjoint and Taguchi methods, and to propose an intelligent integration of two methods which can solve the trade-offs in the marketing and R&D domain in NPD.

Literature review

Interface between marketing domain and R&D domain

The marketing-R&D interface is especially difficult in the case of a new product (Shapiro, 1977). However, many models and scientific evidences have suggested that firms are more successful in their NPD if there are good communications and cooperations between marketing and R&D divisions (Olson *et al.*, 2001; Griffin and Hauser, 1992). In addition, there have been a number of recommendations for increasing success rates of innovation projects by using a model that improves the conditions at the marketing-R&D interface (Souder, 1988). It has been shown that collaborative efforts between the marketing and R&D interface during the actual design of new products appear to be a key factor in determining success levels of new products (Hise *et al.*, 1990).

Besides these studies of above demonstration, many conceptual frameworks and propositions about the marketing-R&D interface have been proposed. For example, some models and propositions posit that the degrees of integration for which a firm should strive to depend on organization's innovation strategy and perceived environmental uncertainty within which the firm operates (Gupta *et al.*, 1986), and another model shows which examine how, how effectively, and why marketing personnel interact with personnel in other functional areas when planning, implementing, and evaluating marketing activities (Ruekert and Walker, 1987). Also there is an integrated approach for concept generation and selection that leverages the unique strengths of marketing, design, and manufacturing in developing a successful product (Srinivasan *et al.*, 1997).

Relation with NPD methodologies
Research studies can be classified into two groups. One is the study on the relationship between the conjoint analysis and the QFD, and the other is the study on the relationship between the Taguchi and the QFD.

First, studies on the relationship between the conjoint analysis and the QFD are composed as follows. The conjoint analysis could be used first to determine the most important features that need to be considered in a subsequent the QFD study. Alternatively, after the QFD screens a problem down to a smaller number of features, the conjoint analysis could be used to refine feature levels and improve prediction. However, Pullman *et al.* (2002) recommended a hybrid approach in which the conjoint analysis and the QFD were used together. On the other hand, Katz (2004) suggested that they should be used sequentially, with the QFD always preceding a conjoint analysis. The target value of the important features from the QFD could be determined by the conjoint (Gustafsson, 1993).

Second, studies on the relationship between the Taguchi and the QFD are composed as follows. Chu (1996) suggested a robust quality design model that integrated the QFD and the Taguchi method, and the technical evaluation of a product in the QFD was enhanced by the Taguchi's loss function (Terninko, 1992). The best parameter values for a robust design can be determined by the Taguchi method, and the customer driven priorities are provided by the QFD. Therefore, the synergy effect of these two systems of design provides some advantages (Terninko, 1997). In recent studies, it is proposed that a combination of the QFD and the Taguchi concepts is the key quality tools that can be applied systematically across product development cycles to achieve continuous improvement and the total customer satisfaction (Al-Mashari *et al.*, 2005). Park *et al.* (2005) applies the Taguchi's robust design method as another method of the S/N-QFD for obtaining the House of Quality (HOQ) top matrix weights.

In sum, although there have been a variety of studies done on the relationship and integrated solution of NPD processes, the usable parts of the conjoint analysis and the Taguchi method are clearly distinguished, and these methods are not compared each other and used in parallel.

Research design
Figure 1 shows the research design framework of this paper. There are two steps in the interface design between the two domains in the proposed process.

The first interface is to determine important design features by using HOQ. The HOQ was formed based on the belief that products should be designed to reflect customers' desires and tastes. Therefore, marketers, design engineers and manufacturing staffs should closely work together from the time when a product idea or concept is decided (Hauser and Clausing, 1988), and the most important design features are determined for NPD. In this step, the marketing domain applies result of the multivariate statistical analysis from customer survey to the HOQ, and the R&D domain applies domain knowledge of expert in the R&D to the HOQ.

The second interface is to compare results of the conjoint analysis in the marketing and the Taguchi method in R&D by using determined important design features. Moreover, the assumption that results of two methods are different is verified in the illustration section. Then this study presents the sequential integrated parameter design process which solves the trade-offs in those two methods.

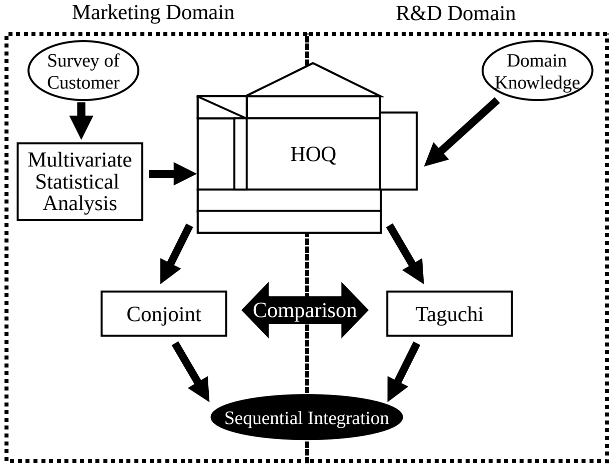

Figure 1.
Research design

Conjoint analysis
Conjoint analysis is mostly used in the marketing domain (Green and Srinivasan, 1990), and the objective of this method is to decompose attributes of a product so that it can be easily inferred from the respondents overall evaluation of the stimuli where each attribute will be utilized. The results are analyzed to determine an optimal attribute levels that can give the highest customer satisfaction. This satisfaction is valued at utility by part-worth, and the formula of utility is as follows:

$$U(x) = \sum_{i=1}^{n} \sum_{j=1}^{m_i} a_{ij} x_{ij} \tag{1}$$

n – number of attribute, m_i – number of level of ith attributes, a_{ij} – part-worth of jth level of ith attributes.

Taguchi method
The purpose of the Taguchi parameter design is to determine the optimal condition that satisfies a target value of control variables and has robustness to noise variables by maximizing the signal to noise ratio (SN ratio). In the SN ratio, the signal is what the product is trying to deliver, and the noise is the interference that degrades signal some of which comes from the outside and some from complementary systems within the product (Taguchi and Clausing, 1990).

The formula used for the SN ratio is different depending on the goal of the experiment. In "the smaller the better" case, the experimenter is interested in minimizing the response, in "the larger the better" case, the experimenter is interested in maximizing the response, and in "target is best where" case, the experimenter wishes for the response to attain a certain target value. The formula of SN ratio is as follows:

$$\text{The smaller the better:} \quad \mathrm{SN} = -10 \log \left[\frac{1}{n} \sum_i y_i^2 \right] \tag{2}$$

$$\text{The larger the better: } \quad SN = -10\log\left[\frac{1}{n}\sum_i \frac{1}{y_i^2}\right] \tag{3}$$

$$\text{Target is best where: } \quad SN = 10\log\left[\frac{(1/n)(s_n - s^2)}{s^2}\right] \tag{4}$$

Where $s_n = (y_1 + y_2 + \cdots + y_n)^2/n$.

Integrated design process

In the parameter design step of a new product, the purpose of the conjoint method is to maximize customer satisfaction, and that of the Taguchi method is to minimize the quality variability caused by noise factors. As two different methods with different purposes are used in the two domains, the results of optimal level condition from each method can be different. Therefore, if the product designer uses either of the two methods, there is bound to be trade-offs between the utility of the conjoint and the SN ratio of the Taguchi method.

When the conjoint method is selected, the difference in the quality increases due to the low SN ratio. In addition, the variability of the customer satisfaction increases according to customer characteristics and the circumstance of using. On the other hand, when the Taguchi is selected, the level of the customer satisfaction on the product parameter decreases due to low utility, which can lead to the lower demand of product. However, any newly designed product should be robust to variations, both in product performances and consumer preferences (Luo *et al.*, 2005). Thus, it is necessary that the integrated design process satisfies both purposes by using an intelligent integration.

Consequently, this study proposes an integrated design process which can solve the trade-offs between marketing domain and R&D domain. The whole process is shown in Figure 2. The integrated design process consists of four steps. Each step is explained in detail in the next section.

Step 1. HOQ integrated with multivariate statistical analysis

The marketing domain transfers significant results of the various multivariate statistical analyses of customer survey and the experiments into the HOQ. This method can provide information that is not well-known but significantly related by using multivariate statistical analysis. Therefore, the modified HOQ can be said to be more effective approach for the customer than any other current HOQ. The process is shown in Figure 3.

First, customer needs are chosen from the customer requirements of the survey conducted on customers through the factor analysis and the correlation analysis. The analytic hierarchy process (AHP) that determines the degrees of the importance of the customer need (Armacost *et al.*, 1994). Second, product characteristics are chosen from the technical requirements of the survey conducted on the customer through the factor analysis which selects significant design variables. Third, the regression analysis is used with the customer needs as dependent variables and the product characteristics as independent variables. Then, the clustering analysis with

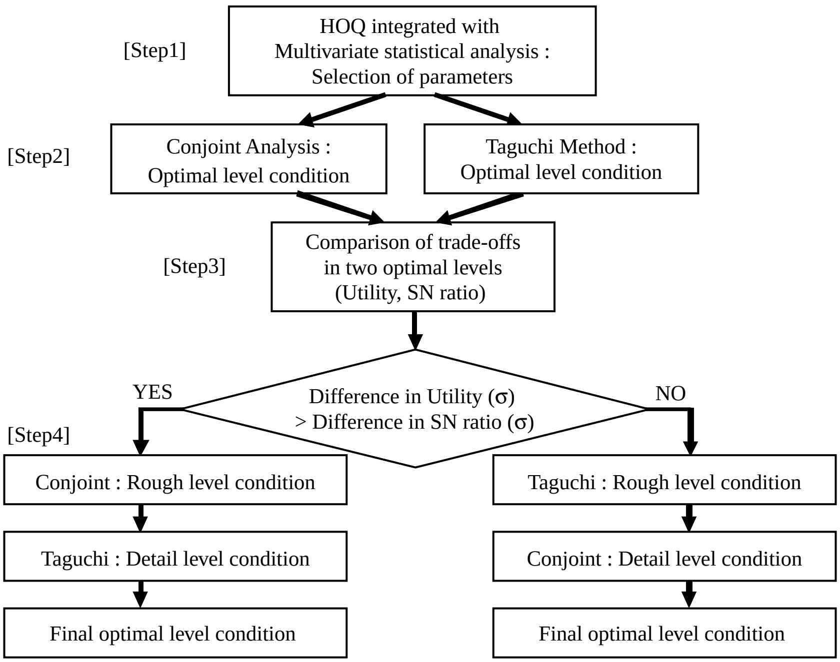

Figure 2.
The integrated design process for optimal parameter level condition

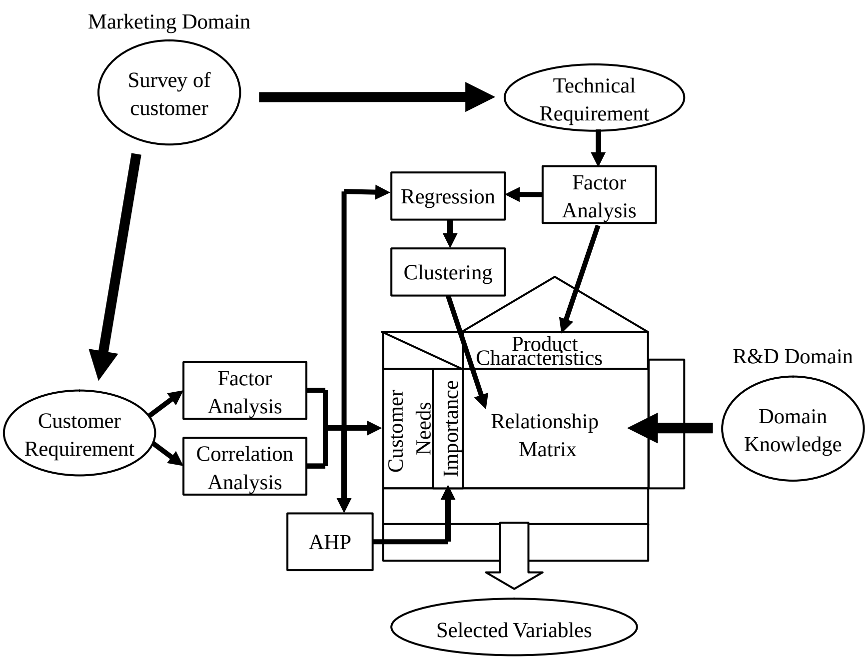

Figure 3.
HOQ integrated with multivariate statistical analysis

the absolute value of significant coefficients in the regression model is used and the clustering results are transferred into the scores of the relationship matrix in the QFD. Forth, the domain knowledge in R&D domain is reflected into the relationship matrix, and accordingly the score results of the marketing domain are adjusted. Then, the final relationship matrix of HOQ is completed. Lastly, the importance of the product characteristics as the final result is calculated by the score results of the relationship matrix and the importance of customer needs.

From this, the product characteristics with high importance scores are selected as design variables to be considered in the product development. Then, in the next step, the optimal level condition of these design variables is determined by using the conjoint analysis and the Taguchi method together.

Step 2. Optimal level condition design in conjoint and Taguchi

The conjoint analysis and the Taguchi method are used to determine each optimal level condition of design variables that were selected in the previous step. First, we determine a dimension range of the design variables as levels according to characteristics of products, and choose the orthogonal array table that fit the number of variables and levels. Second, after experiments are conducted on the products in orthogonal array table, we use the conjoint analysis and the Taguchi method to determine optimal level condition. The conjoint analysis selects levels of design variables that have the highest part-worth, and this optimal level condition of conjoint analysis has the highest utility. The Taguchi method selects levels of design variables that have the highest SN ratio, and this optimal level condition of the Taguchi method has the highest total SN ratio.

Especially, the most important factor considered in this step is the noise factor. Although the conjoint analysis and the Taguchi method use the same experimental results of the orthogonal array table, the analysis on the noise factor is used only in the Taguchi method. Therefore, it is important to determine and define noises which affect most variance of quality as purpose of design.

Step 3. Comparison of trade-offs in two optimal level conditions

We analyze the trade-offs of the results of the conjoint analysis and Taguchi method after comparing the two optimal level conditions in the previous step. First, we measure the utility of the Taguchi's optimal level condition based on the utility function of the conjoint method, and measure the SN ratio of the optimal level condition of the conjoint analysis based on the SN ratio function of the Taguchi. Then, we calculate the difference in the utility of the conjoint analysis and Taguchi method, as well as the difference in the SN ratio of the two methods. However, as the scales and ranges of utility and SN ratio are different, they need to be converted into z-value by using the standard normalization as presented in the formula (5):

$$\frac{x - \mu}{\sigma} \tag{5}$$

μ – average of x; σ – standard deviation of x.

This formula is used to compare the x-values of the different normal distribution. Then, we can compare the z-value and consider it to indicate the difference in the conjoint analysis and the Taguchi method.

If the difference in utility in the two methods is greater than the difference in the SN ratio, this means that the product design is more sensitive to utility than to SN ratio.

Therefore, when the optimal level condition of the conjoint is chosen, the gain of utility is greater than the loss of the SN ratio. On the other hand, if the difference in the SN ratio in two methods is greater than the difference in utility, this means that the product design is more sensitive to SN ratio than to utility. When the Taguchi's optimal level condition is chosen, the gain of the SN ratio is greater than the loss of utility. In sum, after analyzing the trade-offs resulting from the difference in the utility and SN ratio, we can choose one method which has to precede the other.

Step 4: Sequential integration

When the difference in utility is greater than that in SN ratio, we can determine the rough level condition by the conjoint method, and then determine the detail level condition within the rough level condition by using the Taguchi method. This is the optimal level condition that cannot only maximize the customer satisfaction in rough level, but also minimize the variation of quality in detail level. On the other hand, when the difference in SN ratio is greater than the difference in utility, we can determine the rough level condition by using the Taguchi method and then determine the detail level condition within rough level condition by using the conjoint analysis. An example of the result of this process is presented in Table I.

The dimensions of design variable A and B are divided into two levels 1 and 2. In case (i), the rough level of design variable A is determined as 1 by the conjoint method, and then the detail level is determined as 2 by the Taguchi method. Therefore, the final optimal level of A is like the second of the four levels.

Finally, a compromise of the strengths of the two methods is made by determining the priority of the customer satisfaction and the robustness of quality, and using them sequentially.

Illustration: automotive interior design

To illustrate how well the integrated design method is applied, the automotive interior design is shown as an example. From the industry-academic project of Korean domestic automobile company in which the first author participated, we could obtain the source of the data by conducting an experiment about automotive interior design. The parts of the collected data with the consent are used to propose the integrated design process for the illustration in this research. The objective of the automotive

Rough level	Detail level	Design variables	
(i) Difference in utility(σ) > difference in SN ratio(σ)			
Conjoint	Taguchi	A	B
2	2		
	1		□
1	2	□	
	1		
(ii) Difference in SN ratio(σ) > difference in utility(σ)			
Taguchi	Conjoint	A	B
2	2		
	1	□	
1	2		□
	1		

Table I. The result example of sequential integration interior design in this illustration is to determine the optimal level condition of interior design variables in order to maximize openness in a driver's seat. The approach to openness of automobile is closely connected with Kansei engineering (Nagamachi, 2002) which was developed as a new user-oriented approach for NPD. As the mechanical performance of passenger vehicles reaches satisfactory levels, this approach is significant because customers are concerned with the ergonomic and aesthetic aspects of the interior design (You *et al.*, 2006).

Data

In the preliminary experiment, evaluations on 30 vehicles were conducted on 25 Korean males in their 20s. The main focus of the evaluation was about satisfaction of 11 sensibilities including openness as the main purpose, and about satisfaction (e.g. close or far, high or low) of 24 interior design variables around driver's seat. Participants were asked to evaluate on 11 sensibilities on a 100-point scale, and 24 design variables on a nine-point Likert scale.

In the main experiment, an orthogonal array table was made by using selected variables in the modified HOQ. Evaluation on eight vehicles that fell under the categories of the orthogonal array table was conducted on 11 Korean males. Participants were asked to evaluate the selected variables one after another in five driving postures including the standard, front, rear, up and down in the same manner as the first experiment. Table II shows 11 sensibilities evaluated in this case, and Table III shows 24 interior design variables.

Drawing the HOQ integrated with multivariate statistical analysis

The modified HOQ was made out for selecting the important considerable design variables which have to satisfy customer needs.

Customer needs. The main customer need is defined as openness which is the purpose of interior design in this illustration. However, the definition of openness is ambiguous, and so detail sensibilities were selected additionally to elaborate the meaning of openness. The factor analysis of multivariate variables in Table II is shown in Figure 4, and the correlation analysis between openness (s11) and detail sensibilities is shown in Table IV.

From the result of two analyses, roominess (s10) and oppressiveness (s6) can be selected as customer needs additionally for supporting openness (s11).

Table II.
Sensibilities

Variable	Sensibility
s1	Closeness
s2	Comfortableness
s3	Refreshment
s4	Novelty
s5	Satisfaction
s6	Oppressiveness
s7	Distance
s8	Recognition
s9	Dynamic
s10	Roominess
s11	Openness

Variable	Design factor
x1	Ceramic coating amount
x2	Overhead console volume
x3	Roof height
x4	Head-lining location
x5	Sun visor volume
x6	Inside rear-view location
x7	Mountain-stay shape
x8	Cluster housing height
x9	Cluster housing width
x10	Hood amount
x11	Windshield distance
x12	Windshield slope
x13	A-pillar slope
x14	A-pillar volume
x15	Handle distance
x16	Center fascia slope
x17	Gage-cluster volume
x18	Right console box height
x19	Center fascia volume
x20	Steering wheel center volume
x21	Door height
x22	Door space
x23	Door trim volume
x24	Outside mirror distance

Table III. The list of design variables

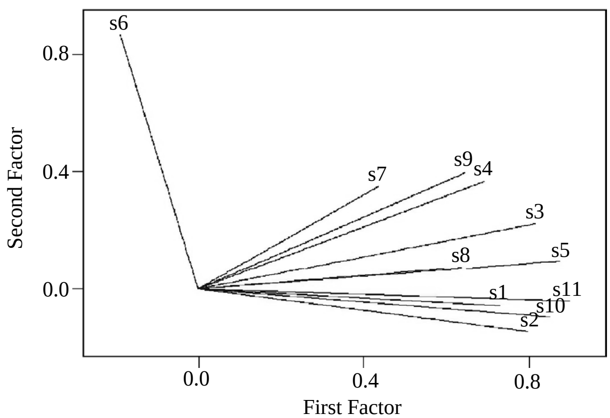

Figure 4. Factor analysis of sensibilities (PCA and varimax factor rotation)

Product characteristics. The factor analysis is used to determine product characteristics from experiment results of 24 design variables. Table V shows important variables that represent each factor derived from the factor analysis, and 13 variables (x2, x3, x4, x6, x8, x9, x10, x12, x13, x14, x16, x21, x23) are selected as important variables.

Relationship matrix. We defined three sensibilities (openness, roominess and oppressiveness) as dependent variables and defined 13 design variables as

	s11
s1	0.599 (**)
s2	0.684 (**)
s3	0.655 (**)
s4	0.556 (**)
s5	0.755 (**)
s6	− 0.170 (**)
s7	0.424 (**)
s8	0.564 (**)
s9	0.531 (**)
s10	0.773 (**)
s11	1

Notes: $^{*}p < 0.05$; $^{**}p < 0.01$

Table IV.
Correlation analysis of sensibilities

Variable	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7
x3	*0.685*	0.012	0.123	0.053	0.003	− 0.040	− 0.013
x6	*0.625*	0.094	− 0.101	0.038	0.053	0.101	− 0.083
x4	*0.622*	− 0.015	− 0.076	− 0.017	− 0.105	− 0.023	− 0.082
x2	0.014	*0.642*	0.030	− 0.005	0.132	− 0.100	− 0.104
x10	− 0.103	*0.496*	− 0.447	− 0.025	0.030	0.226	0.059
x14	0.001	*0.478*	0.136	0.345	− 0.060	− 0.040	− 0.069
x9	0.024	0.051	*0.653*	− 0.087	− 0.049	0.021	0.380
x8	0.076	− 0.059	*0.545*	− 0.008	0.115	− 0.200	− 0.170
x13	0.058	0.030	− 0.130	*0.744*	0.095	− 0.124	− 0.077
x12	− 0.025	0.045	0.084	*0.707*	0.025	− 0.007	0.123
x23	0.021	− 0.052	0.059	0.056	*0.719*	0.208	− 0.041
x16	− 0.002	0.156	0.081	0.203	− 0.159	*− 0.612*	0.118
x21	0.209	0.247	0.088	− 0.090	− 0.066	− 0.059	*− 0.659*

Note: PCA and varimax factor rotation

Table V.
Factor analysis of product characteristics

independent variables. After regression, we divided the absolute values of coefficients in the regression to three clusters by using nonhierarchical clustering. Since, a large absolute value of coefficient means that the design variable has strong influence on sensibilities. We gave 1, 3, and 5 scores to each cluster, and gave 0 score to the variables whose p-value is not significant (<0.05). Table VI shows the results of the relation score in HOQ from regression and clustering.

Then, we transferred the customer needs, product characteristics and relation score selected in the marketing domain into HOQ. Then, by using R&D domain knowledge of the experimenters, we mediated and revised the relation scores. Lastly, the importance of customer needs is determined by AHP, and we could draw HOQ as shown in Figure 5.

From this HOQ, we selected six design variables which are x3, x4, x14, x21, x16, x8 according to the score sequence.

Table VI. Scoring by regression and clustering

Dependent variable	Openness				Roominess				Oppressiveness			
Independent variable	Coefficient	*P*-value	Cluster	Score	Coefficient	*P*-value	Cluster	Score	Coefficient	*P*-value	Cluster	Score
(constant)	55.747	0.000	–	–	48.006	0.000	–	–	80.711	0.000	–	–
x2	0.565	0.032	3	1	0.699	0.010	3	1	0.047	0.911	–	0
x3	1.414	0.000	1	5	1.525	0.000	1	5	−1.803	0.002	2	3
x4	0.031	0.933	–	0	−0.011	0.977	–	0	−1.054	0.073	–	1
x6	0.935	0.027	2	3	1.122	0.010	2	3	−3.805	0.000	1	5
x8	−0.321	0.363	–	0	−0.280	0.439	–	0	−0.599	0.287	–	0
x9	−0.227	0.479	–	0	−0.213	0.517	–	0	−1.054	0.040	3	1
x10	0.822	0.001	2	3	0.443	0.071	3	1	−0.255	0.505	–	0
x12	0.468	0.165	–	0	0.365	0.291	–	0	0.921	0.088	3	1
x13	−0.427	0.256	–	0	−0.114	0.766	–	0	−0.851	0.156	–	0
x14	−0.547	0.134	–	0	−0.206	0.580	–	0	−1.134	0.051	3	1
x16	−0.647	0.011	3	1	−0.287	0.267	–	0	0.292	0.469	–	0
x21	−0.318	0.452	–	0	−0.008	0.985	–	0	1.205	0.074	3	1
x23	0.765	0.014	2	3	0.858	0.007	2	3	0.811	0.103	–	0

Design of orthogonal array table

By using six design variables selected in modified HOQ, we prepared the orthogonal array table which has two levels of dimensions for each design variable. We chosen automobiles that fell under the categories of the orthogonal array table for the second experiment.

In Table VII, the level was determined by the CAD data of automobiles. Level 1 means smaller value than mean value of a general sedan, while Level 2 means larger value than mean value of a general sedan.

Optimal level design of conjoint

We conducted a second experiment by using the orthogonal array table designed previously, and from those results, the optimal level condition with the highest utility of design variables in three sensibilities was selected as shown in Table VIII. After considering all conjoint results of three sensibilities, we obtained the optimal level conditions of each sensibility as shown in Table VIII. We were able to evaluate the total utility of the optimal condition.

Optimal level design of Taguchi

Five driving postures (standard, front, rear, up and down) are defined as noise. To make three sensibilities insensitive to the change of driving postures, we choose the optimal level condition that has the highest SN ratio.

In the case of openness and roominess, the larger they are the better, while in the case of oppressiveness, the smaller the better. After considering all three Taguchi results of sensibilities, we could obtain the optimal level conditions of each sensibility as shown in Table IX. The importance of design variable was evaluated by the difference in the SN ratio between Levels 1 and 2.

		Product characteristics												
Customer needs	Importance	x2	x3	x4	x6	x8	x9	x10	x12	x13	x14	x16	x21	x23
Openness	0.5	□	□	□	□			○			□	□	□	○
Roominess	0.25	□	□		□	□		□				○		○
Oppressiveness	0.25		○	□	□	□	□		□		□	□	□	
Overall weighting		0.75	4.5	2.75	2	2.5	0.25	1.5	0.25	0	2.75	2.5	2.75	2.25
Target value														

(□ : 5○: 3□: 1)

Figure 5.
HOQ

Automobile	x21	x4	x3	x8	x14	x16
A	1	1	1	1	1	1
B	1	1	1	2	2	2
C	1	2	2	1	1	2
D	1	2	2	2	2	1
E	2	1	2	1	2	1
F	2	1	2	2	1	2
G	2	2	1	1	2	2
H	2	2	1	2	1	1

Table VII.
Orthogonal array table ($L_8(2^6)$)

Table VIII.
Optimal level conditions of conjoint analysis

Design variable	x21		x4		x3		x8		x14		x16		
Sensibility	O	I	O	I	O	I	O	I	O	I	O	I	Utility
Openness	1	8.46	1	4.53	2	18.83	2	5.84	1	17.52	1	44.82	2.5023
Roominess	1	12.90	2	2.49	2	30.47	1	29.41	1	5.79	1	18.94	3.3754
Oppressiveness	1	9.59	1	22.69	2	25.63	2	11.63	1	8.68	1	21.78	2.9153

Note: O = Optimal level; I = Importance

Table IX.
Optimal level conditions of Taguchi method

Design variable	x21		x4		x3		x8		x14		x16		
Sensibility	O	I	O	I	O	I	O	I	O	I	O	I	SN ratio
Openness	1	8.81	1	27.19	1	0.45	2	19.98	2	8.78	2	34.80	36.867
Roominess	1	14.33	1	35.22	1	4.81	2	28.95	2	5.53	1	11.17	37.190
Oppressiveness	2	13.37	2	15.21	1	23.31	1	14.91	2	30.58	2	2.62	−30.288

Note: O = Optimal level; I = Importance

Comparisons of two optimal level conditions and analysis of trade-offs

Comparing the results of the conjoint analysis and the Taguchi method, we can compare the difference in the parameter design method between the marketing domain and R&D domain. Table X shows the results of comparison of two methods in each sensibility.

In addition, Table XI shows the result of the comparison of two overall optimal level conditions that combines results of three sensibilities.

To determine the overall optimal level condition, we gave priority to result of openness, and the design variable which was less important in openness was complemented by optimal level of other sensibilities that was more importance relatively than openness.

From these comparison results, we can verify that optimal level conditions of the conjoint analysis and Taguchi method are different with respect to openness. Also, the importance of each design variable is different in the two methods. To compare the opportunity cost of two optimal level conditions, we evaluated both the utility and SN ratio in two optimal level conditions, and converted the differences in the utility and SN ratio into the $z\sigma$ by using formula (5). Table XII shows the evaluation results of the differences of the two methods in each sensibility, and Table XIII shows the result of two overall optimal level conditions.

From the comparison of the differences in the utility and SN ratio, we can see that the difference in utility is greater than the difference in SN ratio in all cases. Especially, in the case of openness, the difference in utility is 2.8716σ, which is larger than that in SN (1.4709σ). In the case of the overall optimal level condition, the difference in utility is 2.6650σ, which is also greater than that in SN ratio. Therefore, we conclude that in automotive interior design for openness, utility is more sensitive and important than SN ratio.

Optimal level condition of sequential integration

In the previous section, we explained that the difference in utility was greater than the difference in SN ratio, and obtained overall optimal level conditions of two methods. Therefore, after determining the rough optimal level condition by using the conjoint analysis, we determined the detail optimal level condition within rough optimal level by using the Taguchi method. This result is shown in Table XIV.

According to the integrated design process, the detail optimal level condition of the Taguchi method has to be obtained by performing additional experiment after the conjoint analysis. However, we used the optimal level condition of Taguchi in Table XI as the alternative to additional experiment. This result indicates that the optimal level condition of integrated process can give a driver overriding satisfaction of openness, and variability of this satisfaction cannot be comparatively large in change of driving postures

Discussion

The integrated design process proposed in the study can find out a point of compromise between the purposes of the conjoint analysis and that of Taguchi method. In addition, by using two methods sequentially, this process ensures that all the advantages of the two methods are utilized and there is no information loss by two methods.

Table X.
Comparison of optimal levels in two methods

		x21		x4		x3		x8		x14		x16	
		O	I	O	I	O	I	O	I	O	I	O	I
Openness	Conjoint	1	8.46	1	4.53	2	18.83	2	5.84	1	17.52	1	44.82
	Taguchi	1	8.81	1	27.19	1	0.45	2	19.98	2	8.78	2	34.79
Roominess	Conjoint	1	12.90	2	2.49	2	30.47	1	29.41	1	5.79	1	18.94
	Taguchi	1	14.33	1	35.22	1	4.81	2	28.95	2	5.53	1	11.17
Oppressiveness	Conjoint	1	9.59	1	22.69	2	25.63	2	11.63	1	8.68	1	21.78
	Taguchi	2	13.37	2	15.21	1	23.31	1	14.91	2	30.58	2	2.62

Note: O = Optimal level; I = Importance

The discussion issues can be summarized as follows. This process first focuses on the main effect which is important in each domain by using the same orthogonal array table for the Taguchi and conjoint analysis. Then, the process selects more important domain by measuring the variance of parameters with normalizing method as the interface system. In depth discussion, when we determine the detail optimal level of the R&D domain within the rough optimal level of the marketing domain, customer would feel overriding satisfaction in product and would not be sensible of the large variation in the product quality. Likewise, when we determine the detail optimal level of the marketing domain, they feel vice versa. For example, in Table XIV, we fix the rough level of conjoint to Level 1 and study the main effect of only Level 1. Additionally, in detail level of the Taguchi, we select a level flexibly by studying both of Levels 1 and 2. Consequently, this process can connect marketing and R&D domain intelligently by using hierarchical planning with the orthogonal array and the normalizing method.

In a holistic or systematic view, this paper provides a modified guideline of six sigma approach which is representative method in process and product innovation of advanced company (Raisinghani *et al.*, 2005). In the case of NPD, in order to satisfy customer needs, we should minimize the variation of quality and consider time to market by integrating the marketing and R&D process effectively. Also, we should concentrate more on efficient optimization of holistic process in value chain than the optimization of each stage in process. Thus, the proposed process in the study can be applied to another domain in value chain by providing a better intelligent integration methodology which phases down variation. For example, if another domain, such as inbound logistics in value chain, needs an optimizing methodology like the conjoint analysis in marketing,

Design variable	x21	x4	x3	x8	x14	x16
Conjoint	1	1	2	1	1	1
Taguchi	1	1	1	2	2	2

Table XI. Comparison of two overall optimal levels

Sensibility	Measure method	Conjoint	Taguchi	Difference
Openness	Utility	2.5023	-1.5599	2.8716σ
	SN ratio	36.5116	36.8673	1.4709σ
Roominess	Utility	3.3754	-1.226	2.6259σ
	SN ratio	34.6363	37.1903	2.5766σ
Oppressiveness	Utility	2.9153	-2.9153	4.2382σ
	SN ratio	-37.3870	-30.2875	4.0173σ

Table XII. Comparison of differences of two methods in each sensibility

Measure method	Conjoint	Taguchi	Difference
Utility	2.2101	-1.5599	2.6650σ
SN ratio	36.3502	36.8673	2.1383σ

Table XIII. Comparison of differences of two overall optimal level conditions we can apply the integrated process which could phases down variation by using the orthogonal design and the normalizing method of interface system.

In supply chain management as an advanced element of value chain which is the integration of suppliers, distributors, and customer logistical requirements into one cohesive process (Lin *et al.*, 2005), a system of continuous improvement on user satisfaction can be added to this process in order to give feedback of customer evaluation to next product development process (Lee *et al.*, 2006). Moreover, marketing domain should consider the product configuration analysis of customer and should reflect the result for determining important design features (Helo, 2006).

The integrated design process can be applied and expanded universally according to the strategy of enterprise. The NPD as a strategic view point is such a core process playing a major role in achieving success for global competition (Humphreys *et al.*, 2005) that a product quality can be effectively employed as a base for realizing competitive strategy and has been a source of competitive advantages in the last decade (Prajogo, 2007). The brief guideline is as follows. When the strategy of enterprise is to secure more market share of a new product, the conjoint analysis should be used preemptively and the level of parameter should be scale-down to increase the acceptance of the new product. As a result, the higher the degree of customer satisfaction, the higher the return on investment the company will achieve (Ho *et al.*, 2005). On the other hand, when strategy of enterprise is to maintain current market share of the new product, the Taguchi method should be used first and the level of parameter in the method should be scale-down to increase robustness of new product. Consequently, this integrated process will give enterprises the competitive advantages.

Conclusion

The contributions of this study can be summarized as follows. First, this study examined the different views between the marketing domain relying on the conjoint analysis and the R&D domain using the Taguchi method. Second, this study proposed the important variables selection method which integrates a multivariate statistical method into HOQ. Third, this study verified the difference in the results of the two methods, and showed the strengths and weaknesses of each by comparing them with utility and SN ratio. Fourth, this study proposed the new product parameter design process with interface system, which is an integrated design process that has strengths of both the conjoint analysis and Taguchi method. Fifth, this study proposed the guideline to be used by enterprises for applying the integrated design process.

Table XIV. The result of optimal level condition of sequential integration

Rough level	Detail level	Design variable					
Conjoint	Taguchi	Door height (x21)	Headlining location (x4)	Roof height (x3)	Cluster housing height (x8)	A-pillar volume (x14)	Center fascia slope (x16)
2	2						
	1			□			
1	2				□	□	□
	1	□	□				

There are, however, some limitations, requiring further studies to be conducted as follows. First, product performance developed by the integrated design process needs to be verified through a customer experiment. Second, the trade-offs between complexity and effectiveness of integrated process need to be considered. Third, there need to be more illustrations on NPD to verify the proposed process.

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