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Innovation and Technopreneurship for Improving National Economy

Jurusan Teknik Industri
Fakultas Teknik
Universitas Surabaya

DIDUKUNG OLEH DITJEN DIKTI (PHK A3)

KATA PENGANTAR

Selamat datang di *5th National Industrial Engineering Conference* yang bertemakan *Industrial Engineering in a Competitive and Borderless World: Innovation and Technopreneurship for Improving National Economy.*

Menghadapi era perdagangan bebas dan globalisasi, paradigma integrasi sistem dan integrasi bisnis tidaklah cukup untuk menghasilkan keunggulan kompetitif bagi suatu industri. Pelaku bisnis dan industri harus memiliki jiwa inovatif dan entrepreneurship yang berbasis teknologi untuk meningkatkan perekonomian nasional agar mampu memenangkan persaingan pasar global. Dalam rangka menyebarluaskan informasi yang berkenaan dengan paradigma baru ini, Jurusan Teknik Industri, Universitas Surabaya pada tahun 2009 ini meyelenggarakan 5*th National Industrial Engineering Conference.* Seminar nasional ini merupakan program berkala yang turut didukung oleh berbagai pihak yang meliputi pihak pemerintah dan swasta, institusi pendidikan maupun non pendidikan. Sebagai kelanjutan dari 4th *National Industrial Engineering Conference*, seminar ini memilih *Innovation and Technopreneurship for Improving National Economy* sebagai tema utama.

Seminar ini menyertakan 70 makalah terpilih yang berasal dari partisipasi para pemakalah. Berdasarkan latar belakangnya para pemakalah tersebut berasal dari berbagai institusi pendidikan maupun non-pendidikan. Kami sangat berterimakasih atas besarnya partisipasi para peneliti dari industri dan institusi pendidikan ini. Topik makalah yang disajikan meliputi *Innovation System and Management, Technopreneurship, Enterpreneurship Education, R & D Management, Management of Technology, Technology transfer, marketing and commercialization, Science park and incubation center, Product design and development, Ergonomics, safety, health and risk, E-business and E-commerce, Entrepreneurships and technology policy, Industrial and manufacturing systems, Innovation in service, Logistics and supply chain management, Project and program management, Quality management, and Knowledge management.*

Besar harapan kami, melalui Seminar ini, para peserta mendapatkan peluang menambah wawasan, membangun kerjasama antar praktisi dan akademisi serta menginspirasi timbulnya ide-ide baru bagi kemajuan bersama.

Sampai berjumpa di 6*th National Industrial Engineering Conference* !

Surabaya, 2 Desember 2009

Editor

DAFTAR ISI

Keynote Speech

Collaboration: Langkah Mempercepat Inovasi dalam Supply Chain

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Ringkasan

Inovasi seringkali dianggap sebagai suatu “alat” khusus yang melekat kepada seorang entrepreneur karena melalui inovasi “seseorang” akan meng-eksploitasi perubahan menjadi suatu peluang bisnis yang berbeda. Kemampuan Entrepreneurships tersebut, pada awalnya diasosiakan dengan Inovasi pribadi (individual) yang akan memulai suatu bisnis, tapi kini telah berkembang kepada pemahaman Inovasi organisasi, bahkan ke inovasi Organisasi yang diperluas seperti supply chain. Inovasi yang dilakukan organisasi telah dibuktikan oleh banyak perusahaan di Eropa dan USA sebagai suatu strategi bersaing untuk menggantikan strategi “low cost strategy leadership”. Melalui pengalaman perusahaan multinasional, diketahui bahwa pada praktiknya, Inovasi dilakukan secara bertahap, diawali dengan langkah sederhana misalnya focus ke proyek tertentu, lalu inovasi ke sistem, sampai ke inovasi pada seluruh aspek perusahaan. Namun dari pengalaman berbagai perusahaan yang menjadi perintis Inovasi, diketahui kalau langkah yang telah dilakukan cenderung lambat, padahal keberhasilan langkah atau strategi Inovasi terletak pada kecepatan. Upaya dan penelitian yang terus menerus dilakukan oleh praktisi dan akademisi, memunculkan suatu langkah inovatif lain, yaitu Collaboration. Langkah ini mengajak berbagai organisasi untuk bekerjasama dalam lingkup yang lebih luas tanpa dibatasi oleh sekat negara, ideology, kemampuan ekonomi, politik dan kemampuan teknologi untuk menghasilkan dan mengantarkan produk/jasa ke konsumen sesuai value yang diharapkan dan mau dibayar oleh konsumen. Makalah ini akan menunjukkan bagaimana bentuk collaboration tersebut dilakukan oleh berbagai organisasi untuk mempercepat Inovasi dalam supply chain, diantaranya kolaborasi sejak disain product sampai kolaborasi dalam distribusi dan transportasi produk..

Kata kunci: Inovasi, collaboration, supply chain

The Robust Emotional Design:
'An Application of Design of Experiment incorporating with Ergonomics'

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Abstrak

Sebuah produk yang berkualitas haruslah sesuai dengan kebutuhan konsumen. Sekarang ini banyak sekali konsumen bingung memilih produk di pasaran yang memiliki fungsi yang sama. Konsumen secara subyektif menentukan apa yang nantinya akan mereka beli. Desain secara tangguh (robust design) sangatlah penting dipertimbangkan dalam hal ini. Sebuah isu yang penting yang perlu diperhatikan adalah bagaimana menangkap dan menerjemahkan kebutuhan emosional konsumen ke dalam suatu produk. Robust design tersebut dapat tercapai dengan memahami sumber kebisingan (noise) dan mengambil tindakan untuk mengurangi sensitivitas dari produk atau proses terhadap sumber kebisingan tersebut. Sangatlah penting untuk memahami parameter performansi dari suatu produk atau proses yang kritis dan akhirnya tercapai nilai performansi dan variasi yang optimal. Makalah ini menyajikan 2 metodologi tentang desain tangguh (robust design) dengan melibatkan aspek emosi yang diinspirasi oleh penelitian Lai dkk [4]. Konsep Kansei Engineering [6, 7, 8], inner and outer orthogonal arrays, dan signal-to-noise ratio oleh Taguchi [19] memberikan peranan penting dalam metodologi desain ini (emotional robust design). Singkatnya, dengan melibatkan emotional robust design ke dalam suatu produk, hal ini akan menguntungkan konsumen dan produsen. Diharapkan nilai kompetitif dari suatu produk atau produsen akan bertahan karena pangsa pasar akan meningkat berkaitan dengan turunnya harga ke konsumen.

Kata Kunci: Robust design, *Kansei* Engineering, emotional design, inner and outer orthogonal arrays, signal-to-noise ratio, Taguchi

Abstract

When product is useful to customers and meeting customer's requirement, the product is said to be qualified. Nowadays, many products will be functional equivalent and therefore hard to distinguish between for the customers. Customers tend to subjectively choose the products that they will purchase. Robust design is important to be considered to address this today's consumer trend in the product development. One big issue for product designer today is to be able to capture the customer's considerations and feelings (emotions/kansei) of products and translate these emotional aspects into concrete product design. This robust design could be achieved by understanding the potential sources of noise and take actions to desensitize the products or processes to these potential sources of noise. It means that it is important to understand the critical process or product parameters of a desired performance and finally to obtain the optimal value of performance and variation (noise). This paper provides 2 methodologies of emotional robust design which is inspired by previous study by Lai et al [4]. The Kansei Engineering concepts by Nagamachi [6, 7, 8], inner and outer orthogonal arrays and signal-to-noise ratio by Taguchi [19] play important role in the emotional robust design methodologies. In short, by involving the robust emotional design into the product, it will be benefiting to both consumers and manufacturers. It is hoped that the competitive value of products or

manufacturers is highly sustained since the market share will increase due to the lower costs for the consumers.
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Keywords: Robust design, *Kansei* Engineering, emotional design, inner and outer orthogonal arrays, signal-to-noise ratio, Taguchi

1. Introduction

1.1 From traditional into modern: quality perspective

When product is useful to customers and meeting customer's requirement, the product is said to be qualified. The customer's requirement with respect to a given measured feature such as production rate, production time, power output etc, can be represented by lower and upper specification unit. By testing and inspection as traditional approaches, there will be potential lost to customers which are α error and β error. In addition, by the error-free inspection (no α error and β error) the customers have to pay for the correctly rejected unit which is a higher price set by manufacturer. Since the price set by manufacturer is higher, the manufacturer has to suffer a loss of profit.

The other weakness of traditional approach is that there is still a noise in the manufacturing so that there will be opportunities for defective products [2]. Hence, the customers will suffer deeper and the manufacturers will loose of profit. It is important to improve the quality to satisfy the customers by managing the noise. It is hoped that the cost will be reduced as well. It is desirable to aim for quality during the product or process stage. There are three strategic ideas for this, i.e. 100% screening, change technology and robust design. By doing the 100% screening and change technology, it will make either customers and manufacturers get hurt since the result will either wasteful for 100% screening or expensive for change technology [2]. Therefore, the robust design is a better way to improve the quality since the result will cost-free.

1.2 Quality Engineering and Robust Design

The noise factors in Taguchi method could include product noise such as a piece to piece variation in the product features. Robust Design method, also called the Taguchi Method, pioneered by Dr. Genichi Taguchi, greatly improves engineering productivity. Later on the idea of Taguchi came to the optimization of product and process against the environmental and manufacturing noise effects. This concept leads to the way to obtain μ_y closer to the target for y and minimize σ_y^2 [2]. By consciously considering the noise factors (environmental variation during the product's usage, manufacturing variation, and component deterioration) and the cost of failure in the field the Robust Design method helps ensure customer satisfaction.

The way how to apply the experimentation of robust design is very important in achieving low cost during the manufacturing and throughout the product life. Once the current physical system achieves the maturity stage, it is suggested to do the design of experiment (DOE) for the new products and processes. The other way is that by doing a simulation to adjust designs due to potential noise factors. The application of robust design is mainly for managers during the product and process design and development stage since 1990 [2]. Robust Design focuses on improving the fundamental function of the product or process, thus facilitating flexible designs and concurrent engineering. Indeed, it is the most powerful method available to reduce product cost, improve quality, and simultaneously reduce development interval [11].

1.3 The segmentation of design process

To consider quality implications during design, the design process can be segmented into three stages. The first stage, system design, establishes the functionality of the product, the physical product envelope, and general specifications. The second stage, parameter design, establishes specific values for design parameters related to physical and functional specifications. It is during these first two stages that the designer has the greatest opportunity to reduce product costs through effective functional design and parameter specification. The third stage, tolerance design, establishes the acceptable tolerances around each parameter or target. The third stage typically will add costs to the product through efforts to ensure compliance with the tolerances associated with product parameters [10]. Robust design is in the stage of parameter design.

2. How the Robust Design meets the quality

A product or process that is robust when it is designed to be insensitive to the various conditions or noise of its use. There are two issues should be addressed in the robust design which are how to ensure *insensitivity* of performance due to the changes in environmental conditions and how to ensure *insensitivity* of performance due to the variations in the characteristics of components [1].

Robust design could be achieved by understanding the potential sources of noise and take actions to *desensitize* the products_or processes to these potential sources of noise. It means that it is important to understand the critical process or product parameters of a desired performance and finally to obtain the optimal value of performance and variation (noise). In other words, robust design aims to counter or minimize the impact of noise based on statistical characteristics of design parameters [2]. Furthermore, it tries to anticipate the noise which the product may encounter during its useful life; thus design parameters are set at values that would help counteract such unavoidable noise once the product is in the hands of the customers [2]. Noise is the result of variation in materials, processes, the environment and the product's use or misuse. The minimization of variation (noise) is important to reduce "loss to society". But, the minimization of noise will be done without any profit reduction or capital investment, thus benefiting both the manufacturers and customers [2].

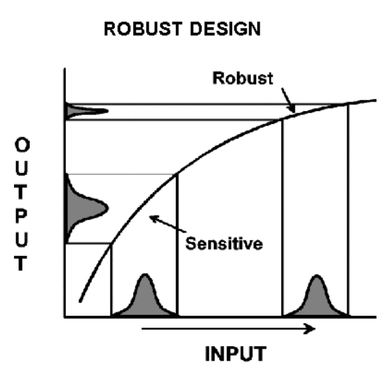

Figure1. Robust design in minimizing the variance [12]

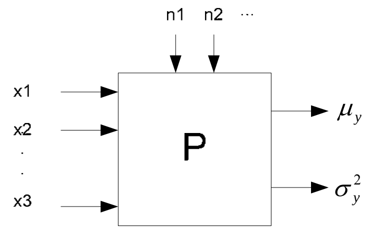

Figure2. Framework for robust design [2]

Figure 1 and 2 show how the robust design will be achieved. By adjusting the product design parameters (input in Figure 1 or x_1, $x_2 \ldots x_k$ in Figure 2), it is hoped that the mean of product performance (output in Figure 1 or μ_y in Figure 2) will be achieved closer to the target value while variance (σ_y^2) will be minimized.

2.2 How to handling the variances

Basically the quality and reliability problem is not from control factors/parameters but from noise factors/parameters. Usually noise is applied only as supporting role:

$$t = \frac{signal}{noise} \quad (1)$$

Therefore, if nothing we can do to the noise, nothing we can do to the quality and reliability too. This is related to the σ^2. In this case, instead of having the noise coming from the top of the model, it is important to treat the noise as response. In the robust design, there are some approaches to handle the variances as follows:

- Direct variance reduction → 2^{k-p} x r
- Control x Noise reduction → simulated noise
- Inner Array x Outer Array → special arrangement with simulated noise
- Transmitted noise → non-linearity
- Manufacturing noise [inner x outer]

This paper shows the proposed methodology of how the Inner Array x Outer Array in the robust design will be implemented in the emotional design.

2.3 Sustainable objective in robust design

The main objective of robust design is to maintain the consistency in quality to achieve customer satisfaction. The long-term performance y of the product or μ_y must be closer to the target as much as possible [2]. The other one is that the minimization of variance should be achieved regardless of all input design parameters and noise factors. Once those objectives are achieved, the final result is benefiting to manufacturer due to minimum cost of materials, parts and every requirements in the manufacturing process [2]. Hence, the competitive value of products or manufacturer is highly sustained since the market share will increase due to the lower costs for the customers.

2.4 Emotional design to meet consumer's need

Nowadays, many products will be functional equivalent and therefore hard to distinguish between for the customer. Customers tend to subjectively choose the products that they will purchase. The current trend in product design has shifted from functionalism (form follows function) to product semantics (form follows meaning) [18].

One big issue for product designer today is to be able to capture the customer's considerations and feelings (emotions) of products and translate these emotional aspects into concrete product design [13]. Modern consumers not only place importance on a product's physical quality, but also employ their sentimental responses when deciding whether or not to purchase a particular product [5]. The sentimental responses are related to the feelings or emotional needs. An evidence was shown by Apple's products such as iMac computer and IPOD which having superior feeling features such as color, they can sell better and better even they left advanced technology. In Japanese word, emotional design is called *Kansei* Engineering. *Kansei* is a Japanese word meaning psychological feeling. This technique is based on subjective estimations of products and concept properties and helps customers to express their emotional demands on the products, even those which they are not aware of.

Nowadays, many consumers make purchasing decisions about products based on how the products make them feel. Manufacturers should therefore strive to produce products that match consumers' desires and feelings, or they will not survive in a fast changing and competitive marketplace [3]. A significant proof also came from the successful Sharp's redesigned video camera which increased its market share from 3% to 25% quickly. *Kansei* Engineering is a powerful ergonomic and consumer-oriented technology that can create new products, human-machine systems, work environments, and social systems [3].

2.5 Robust emotional design and quality

The word quality originates from the Latin word *'qualitas'* and means "of what". The ISO 9000 definition provides a direct connection between quality and the properties of a product: Quality is "the totality of those properties and characteristics of a product or an activity that relate to its suitability to fulfil stated requirements." Even more affective oriented definitions occur and reveal connections to the field of ergonomics: "A product/service is of quality when it makes a maximum contribution to the health and happiness of all people involved in its production, use, destruction, and reuse" [14]. Tribus defines quality in even more emotional terms: "Quality is what makes it possible for a customer to have a love affair with your product or service" [15]. Focusing on product development processes two aspects of the above presented definitions are of importance:

- affective aspects (emotional impact of the new product)
- design aspects (product properties)

Every product possesses a number of properties, which enables it to fulfil the function that it is originally designed for. Generally, the products are divided by two terms as follows [13]:

- design parameters, and
- product traits

The design parameter is intentionally designed main property of the product. In contrast, a product trait is a product property which was not intended by the designer but nevertheless a property of the product. For example: when designing a cell phone, the housing is usually made out of plastic, since it is easy and cheap to produce, light, shock-absorbing and it has a smooth surface. All of them are the intended design parameters. On the other hand the material like the shock absorption, its thermal conduction, which are not originally intended but are now properties of the cell phone [13].

In the robust emotional design, the product traits are called by the uncontrollable factors (noise), whereas the design parameters are controllable factors. Robust emotional design assists the designers in enhancing the feeling quality of their products. How to optimize the design parameters is highlighted. It is difficult to measure the feeling quality of products. The term ‘‘quality’’ which refers to the ability of a product to satisfy the consumers’ requirements and expectations [9] and “lost to society” by Taguchi also can refer to emotional design since it satisfies a certain set of consumer emotional targets. Robust design employs a simple experimental approach to determine the optimal design parameter settings by analyzing the complex relationships among the controllable factors (design parameters), the uncontrollable factors (noise factors), and the quality performance [4]. The relationship among the design parameters and noise factors is shown by the layout of orthogonal arrays (it is shown in the section 2.5.1). The signal-to-noise ratio (SN Ratio) is also given to evaluate the quality of designed product.

2.5.1 Inner and Outer Orthogonal Arrays

Typically, controllable factors are assigned to an orthogonal array, called the inner array. Signal and noise factors are assigned to another array called the outer array. An experimenter or a simulation is conducted for all combinations between the inner and outer arrays. To conduct parameter design, the use of orthogonal arrays such as L_{12} and L_{18} for the inner array is recommended. L_{12} is used for 2-level factors and L_{18} for 3-level factors. For the outer array, either a simple orthogonal array such as L_4 or L_9 can be used to assign both signal and noise factors. Here is one example of layout of an orthogonal array with objective of closeness to target:

Table 1. Layout of an orthogonal array with objective of closeness to target [16]

Control Factor																
Test	A	B	C	D	E	F	G	H	I	J	K	Noise Factor			η	$\bar{y}$
No	1	2	3	4	5	6	7	8	9	10	11	N_1	N_2	N_3		
1	1	1	1	1	1	1	1	1	1	1	1	oo	oo	oo	η_1	$\bar{y}_1$
2	1	1	1	1	1	2	2	2	2	2	2	.				
3	1	1	2	2	2	1	1	1	2	2	2	.				
4	1	2	1	2	2	1	2	2	1	1	2	.				
5	1	2	2	1	2	2	1	2	1	2	1					
6	1	2	2	2	1	2	2	1	2	1	1					
7	2	1	2	2	1	1	2	2	1	2	1					
8	2	1	2	1	2	2	2	1	1	1	2					
9	2	1	1	2	2	2	1	2	2	1	1					
10	2	2	2	2	1	1	1	2	2	1	2					
11	2	2	1	1	1	2	1	1	1	2	2					
12	2	2	1	1	2	1	2	1	2	2	1	oo	oo	oo		

SN ratio = η = 10 $\log_{10}(\bar{y}^2/\sigma^2)$, where $\bar{y}$ = average and σ^2 = variance around the average.

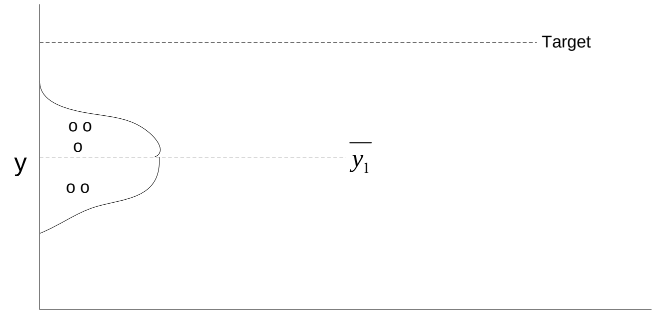

Figure 3. SN ratio with objective of closeness to target

2.5.2 Signal-To-Noise Ratio (SN Ratio)

In quality engineering, the concept of SN ratio has been adapted to evaluating the quality of a product or a manufacturing process. Conceptually, SN ratio is the ratio of signal to noise in terms of power. From another viewpoint, SN ratio represents the ratio of sensitivity (or "average" in non dynamic terminology to variability). Traditionally, the research for a product or a manufacturing process aims for a target, a fixed target, in the first place. Parameter Design tries to maximize the SN ratio by changing parameter level of the control factors associated with the product's design [16].

According to Taguchi's philosophy, the criteria of SN ratio should differ depending on the objective of the experimenter [1]. Some examples are given in the table 2 as follows:

Table 2. Some criterion of SN ratio

Objective	Criterion
Closeness to target	$SN_T = 10\log_{10}(\bar{y}^2/s^2)$
Response as large as possible (the larger the better)	$SN_L = -10\log_{10}(\frac{1}{n}\sum_{i=1}^{n}(1/y_i)^2)$
Response as small as possible (the smaller the better)	$SN_S = -10\log_{10}(\frac{1}{n}\sum_{i=1}^{n}y_i^2)$

3. Problem definition

A consumer's feeling plays an important role in determining which products will meet the consumer's need. If we fail to meet the consumer's need then the risks will exist that the product is a failure before it even enters the market. It is important to propose a robust design so that it is not only to segment the market into particular consumer groups comprising individuals with common characteristics. However, many problems still remain in developing an affective design process which is how to estimate and to enhance this feeling is difficult since a variance exists between different consumer's evaluations [4]. Intensive market competition now compels product developers to meet very short development cycle times and to address the demands of highly diverse target markets [4]. Many *Kansei* Engineering have proposed methods to infer a prototype which will generate the required consumer feeling [[6], [7], [8]], but they lack flexibility which allows them to be applied to diverse market [4].

This paper shows and develops the methodology of robust design to enhance the quality of products by (i) bringing the response closer to the target and also (ii) reducing the discrepancy between the actual consumer feeling and the target feeling. In addition, it is hoped that robust design concept will counter or minimize the impact of noise based on statistical characteristics of design parameters.

4. The objective

The objective of this paper is to apply the robust design concept to create a method in enhancing the consumer's emotional needs which can minimize the uncontrollable noise and have a competitive advantage in the market. It is hoped that the robust design will improve the feelings (emotional needs) quality of products.

5. Methodology

This paper proposes 2 methodologies which can be useful for the product planning and development phases based on the consumers' emotional needs. The detailed phases are as follows:

5.1 Methodology I

There are several steps in the robust emotional design as follows:
Phase 0: to determine the particular product will be made and developed
Phase 1: to identify the controllable factors which influence the products. It is likely to include material, temperature, and many things
Phase 2: to identify the uncontrollable factors (noise) which also can contribute to the performance of products
Phase 3: to identify the crucial images of products related to the emotional *(kansei)* needs for the controllable and uncontrollable factors. How the consumers grasp the image of a product in terms of psychological estimation is important. The techniques proposed in *Kansei* Engineering [6, 7, 8] is useful to grasp the people's perceptions about the product form.
Phase 4: to set levels of controllable factors and uncontrollable factors
Phase 5: to select inner and outer orthogonal array (OA). The inner OA is specified according to the number of controllable factors (i.e. product design parameters) and levels. The outer OA is specified in accordance with the number of uncontrollable factors (i.e. consumer characteristics) and levels.
Phase 6: to array the experiment and generate experimental samples
Phase 7: to explore the consumers' perceptions about the products based on the controllable and uncontrollable factors for n numbers of consumers. The consumers will be given a drawing design in a piece of A4 paper of each combination factors and their levels. The Semantic Differential (SD) method could be used to explore the consumers' perceptions about product form [17]. In the SD test, image and preference perception will be scored according to a 9-point scale. A bipolar pair of descriptive adjectives defines the attribute scale, with the positive word on the right and its negative counterpart (antonym) on the left. On this evaluation scale, a score of 9 points means that the subject has a very strong positive

impression of the sample (combination of several levels of factors), while 1 point means a very strong negative impression [17].

Phase 8: to calculate the S/N ratio with objective of closeness to target (it is assumed that the closeness to target is chosen as a criterion). The S/N ratio in this case is $SN_T = 10 \log_{10}(\bar{y}^2 / s^2)$, where $\bar{y}$ = average of consumers' perception and s^2 = variance around the average. Finally, we select the best factor which gains the most desirable result.

5.2 Methodology II

The methodology II is adopted from the study conducted by Lai et al [4]. Some additional parts in certain phase are proposed. There are several steps in the robust emotional design [4] as follows:

Phase 1: to set target feeling. This phase involves the use of preliminary market analysis to specify the position of the target feeling in a feeling space composed of various critical image scales. We could use the *Kansei* Engineering [6, 7, 8] to define what the crucial image of the product. It is also called the step for capturing the *kansei* words (image). There are some steps in this phase:

a. Identify crucial images and evaluation scales
b. Construct multidimensional feeling space
c. Select the position of target feeling

Phase 2: Taguchi experiment. In the second phase, a Taguchi experiment is performed using appropriate inner and outer orthogonal arrays (OA). The inner OA is specified according to the number of control factors (i.e. product design parameters) and levels. The so called ‘‘combinative samples’’ (i.e. experimental product samples) are then separately generated in accordance with the condition array of the inner OA. The outer OA is specified in accordance with the number of uncontrollable factors (i.e. consumer characteristics) and levels. Estimator (consumer) groups are established, and each combinative sample is then evaluated by the individual estimator groups using appropriate image scales. There are some detailed steps in this phase:

a. Identify control factors and setting levels
b. Identify uncontrollable factors and setting levels
c. Select inner and outer orthogonal array
d. Array the experiment and generate experimental samples
e. Perform feeling evaluation experiment

Phase 3: Result analysis. Phase 3 analyzes the results of the preceding Taguchi experiment to obtain the optimal parameters for each factor. The feeling quality of each combinative sample is measured using the ‘‘smaller-the-better’’ S/N ratio since the ideal affective design is the design which yields the minimum feeling discrepancy. The “smaller-the better’’ S/N ratio, is given by

$$\text{S/N ratio} = -10\log_{10}\left(\frac{1}{n}\sum_{i=1}^{n} y_i^{\,2}\right) \qquad (2)$$

where y_i is the feeling discrepancy of the i_{th} group and n is the number of estimator groups in the outer OA. The final objective of phase 3 is to identify the optimal levels (parameters), which reduce this S/N ratio to a minimum value for each factor. There are some detailed steps in this phase:

a. Calculate feeling discrepancy
b. Calculate S/N ratio
c. Select the setting optimal parameters

Phase 4: Improvement and verification. In this phase, ANOVA is employed to identify the most significant factors, and the initial design is then modified accordingly. There are some detailed steps in this phase:

a. Select powerful control factors by ANOVA
b. Redesign initial design
c. Predict the S/N ratio of the improved design
d. Perform verification experiment to confirm the prediction

6. Case study

This paper provides 1 proposed example of Methodology I. Here is the detailed application: The controllable factors of phone product could be material, temperature, machining process, operator etc. On the other hand, the uncontrollable factors might be the usage pattern, charging time etc. After identifying the controllable and uncontrollable factors, the images crucial images of products related to the emotional *(kansei)* needs are defined. Based on the study conducted by Hsu et al. [17], there are some image words pairs can be used for describing the image of phone product as the following:

Table 3. Sixteenth image word pairs used in the SD test [17]

Traditional-modern	Heavy-handy	Hard-soft	Hand-made--hi-tech
Large-compact	Masculine-feminine	Obedient-rebellious	Conservative--avant-garde
Coarse-delicate	Unoriginal-creative	Rational-emotional	Plain-luxurious
Childish-mature	Common-particular	Nostalgic-futuristic	Personal-professional

For discussion, we define 2 controllable factors (A and B) with 2 levels (1 and 2) and 2 uncontrollable factors (N1 and N2) with 1 level. A is related to the shape of phone (large-compact), B is related to weight of phone (heavy – handy), whereas the N1 and N2 are related to environmental conditions (outer noise). Some numerical numbers are presented as the following:

L_4 (2^3) design

Run no.	A	B	A x B	N1	N2	S/N
1	1	1	1	*4.5	9	**-17.04
2	1	2	2	5.625	7.875	-16.71
3	2	1	2	3.375	5.625	-13.33
4	2	2	1	2.25	2.7	-7.91

S/N 1 = -10 log $\left|\frac{4.5^2+9^2}{2}\right| = -17.04$

*Response: it is calculated using SD test which is image and preference perception that will be scored according to a 9-point scale. The data is the average score response from n consumers.

** S/N ratio criteria is using the-smaller-the-better calculation

The signal to noise response table is generated in the same fashion using the S/N values as the mean response table was derived in level average analysis, by combining and averaging the mean response for each factor (and interaction) level. Accordingly, the effect of a factor (or interaction) is equal to the difference between the average S/N for each level (two levels) or the difference between the highest average S/N and the lowest average S/N (more than two levels) [19]. The average signal-to-noise ratio will be calculated as follows:
For A1: S/N = {(-17.04-16.71)/2} = -16.875
For A2: S/N = {(-13.33-7.91)/2} = -10.62
Effect of A = $\left|-16.875-(-10.62)\right|$ =6.255
Here is the detailed response table:

S/N Response Table			
Level	**A**	**B**	**A x B**
1	-16.875	-15.185	-12.475
2	-10.62	-12.31	-15.02
Delta	**6.255**	2.875	2.545

From the table above, factor A is the most influence since it has the greatest delta score. As in any signal-to-noise analysis it is recommended to choose the highest average S/N values. Therefore factor A is highly recommended. Since A2>A1, A2 is recommended. Next, we will proceed with a more in-depth analysis of interaction A x B. Here is the calculation of S/N interaction:

Interaction matrix		
	B_1	**B_2**
A_1	-17.04	-16.71
A_2	-13.33	**-7.91**

It seems that the identification of A_2B_2 is the best interaction combination.

7. Conclusion and recommendation

This paper proposes 2 methodologies of robust emotional design which employs emotional needs into product design. The inner and outer orthogonal arrays by Taguchi is useful to obtain the optimal design parameters which cause the consumers' feelings induced by the redesigned products to be closer to the target feeling than the initial products, while simultaneously reducing the influence of the consumers' highly individualized characteristics. The emotional needs are collected by using the *Kansei* Engineering technique. The advantage of this proposed design is that the present robust design method reduces the time and cost required to complete the feeling evaluation study and obtain the optimal emotional design parameters of the product directly. Therefore, product developers and designers are faced with the challenge of creating and redesigning products which cater to consumers of all types and preferences. Finally, the designed products will compete in the market effectively and efficiently.

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