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Integration of QFD, HOQ, Taguchi, and Kansei Engineering for Smart Desk Lamp Design

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Abstract *— This research focuses on the analysis of smart desk lamps. To the authors' knowledge, there is no previous study about Voice of Customer regarding smart desk lamps in Indonesia, to know the requirements for a smart desk lamp from Indonesian customer using the QFD and House of Quality (HOQ) The overall value of the interaction matrix with HOQ, the relative weight results for each customer and functional requirements are obtained. The highest technical requirement from HOQ is automatic on/off. The Taguchi method is to find out the best design for each Kansei Engineering that has been created. The Kansei Engineering that have been created are easy to use, adjustable lamp, affordable price, modern design, hi-tech. Each Kansei Engineering produces the required design according to the S/N Ratio (signal to noise ratio). Based on the QFD questionnaire and design using Kansei Engineering, one best design was obtained, namely hi-tech. The design consists of 3 parts, namely the top, middle and bottom. At the top, the slim rectangular shape is preferable with lights position in the middle. Pole position is round, upright position. At the bottom, it has a circular shape.*

Keywords: *Smart Desk Lamp; Quality Function Development (QFD); House of Quality (HOQ); Taguchi m=Method*

I. INTRODUCTION

Nowadays, an ordinary house can be the most comfortable place for its owner. A smart desk lamp, which is usually called a smart desk lamp, is a house that is equipped with an operating system that can control many things, such as lighting, namely lights that can be controlled with an on/off control system via a remote. Technological advances in this tool have penetrated human life, such as the discovery of smart desk lamp applications that make it easier for owners to carry out their activities (Susilo et al., 2021). This concept can beapplied to managing electronic equipment in our homes. With the advent of smart desk lamp technology revolutionizing our living spaces, the integration of devices such as lighting controlled remotely has become commonplace. This convenience is exemplified by the emergence of smart desk lamp applications that simplify daily activities. In line with this, the Arduino Nano, a compact microcontroller development board featuring the ATmega328P chip, complements the smart desk lamp concept seamlessly. This Arduino variant, distinguished by its petite dimensions and programmability through a mini USB type B connector, boasts 14 digital i/o pins, 8 analog input pins, and various specialized functions. (Suari, 2017).

However, the limitations of QFD encourage the exploration of complementary tools to improve the design process. One such tool is the House of Quality (HOQ), a matrix-based approach that builds relationships between customer desires and design steps.(Handayani et al., 2020). QFD operates through a four-phase process, where customer requirements are systematically distilled into product characteristics, which are then translated into part characteristics. These part characteristics are then converted into process characteristics, which ultimately lead to the development of production characteristics by the product development team.(Chan & Wu, 2002). In general, mathematical models are used to obtain optimal solutions in the field of logistics and transportation problems. However, in current conditions, this method is not optimal to apply, so SixSigma is preferred in the current method, because it can produce predictions with more optimal results.(Orbak et al., 2023). In conjunction with the Quality Function Deployment (QFD) strategic methodology and the House of Quality (HOQ) tool, another impactful approach in the field of smart desk lamp system development is Kansei engineering. Kansei engineering serves as a method for effectively translating customer feelings and perceptions about a product into tangible design elements, aligned with the overall goal of meeting consumer satisfaction.(Fahrul Huda, 2021). Furthermore, it should be noted that Kansei Engineering, formulated in the 1970s by Mitsuo Nagamichi, is a method that directly translates consumer opinions into design components (Putri Avintya Fatimah Rahma et al., 2023).

In the field of design methodology, "Translating customer Kansei into the product design domain" encapsulates the essence of Kansei engineering. Whether designing a passenger car, considering Kansei elements relating to the exterior, interior, engine, etc., or engaging in urban planning where the wishes of the people are of paramount importance.(Nagamachi et al., 2006). Currently, research investigating user sentiment, particularly Kansei Engineering, directed toward a product and research investigating the complex relationship between product attributes and affective responses, including words Kansei, is research from the two main streams of KE research. This dual approach seeks to offer a comprehensive understanding of consumers' subjective impressions and their affective reactions to an item (Nagamachi, 2002). This study tested different models and chose the best decision tree structure for each emotion. The effects of product properties on customer emotions were mapped, and the most important product categories influencing high emotional levels were identified. This study also used CAR (Class Association Rule) to determine the most important rules for each emotion. model predictions of product properties that affect emotions between J48 and CAR. (Kittidecha & Yamada, 2018). The Kansei Engineering System (KES), connects consumer feelings with design elements, unfolds in the initial four stages of the extensive KES process. This stage includes the systematic collection and classification of consumer feelings, identification of important design elements, and adjustment of product design heuristics to align with consumer emotions. (Tang et al., 2005). This approach functions as a structured procedure, which directly links engineering features, application of parts (components or modules), process planning, and production planning with customer needs. In effect, this ensures that the final product is aligned with initial specifications, providing integration of customer expectations into the entire product development cycle.(Abdul Rahman et al., 2023)providing prevention solutions is the key. This study aims at developing an improved fall detection device using an approach called Quality Function Deployment (QFD. The authors find that factors such as ease of use, durability, and aesthetic appeal are all important to the user, and certain design features, such as the shape of the pot and the material of the handle, have a significant impact on the user experience.(Göken & Alpay, 2023). The prototype couch was evaluated by a group of users who were asked to rate their emotional and sensory experiences while sitting on the couch. Evaluations show that the design of the sofa evokes positive emotional and sensory responses in users. Specifically, users report feeling comfortable, relaxed, and satisfied while sitting on the couch.(ZEYDAN & ÖCAL, 2021)product design has been much more complicated when compared with the past. Shorter product life cycle increased product development cost. In order to stay competitive in the market, a well-designed product should be able to not only meet functionality requirements, but also satisfy consumers' psychological needs (or feelings. Survey results further shed light on user preferences in the digital realm, showing a strong inclination towards simple and organized web designs characterized by high usability and functionality (Turumugon & Baharum, 2018). Positive emotions are associated with design elements such as clear information, easy navigation, and attractive layouts. On the other hand, users express negative emotions towards messy design, slow loading speed, and poor visual appearance.(Hartono, 2020). In the field of product design, research explores the use of Kansei Engineering along with innovative methodologies. A framework for innovative product design based on deep learning and kansei engineering.(Quan et al., 2018). Another study shows that the combination of Kansei Engineering and Fuzzy Analytical Hierarchy Process (FAHP) methods can help in developing packaging designs that are in line with consumer preferences, increasing aesthetic value and consumer attention.(Sari et al., 2020). In addition, insight into the study of rengginang packaging reveals the dominant role of color in the formation of Kansei word images, providing certain design specifications as a reference.(Dwi Orshella, 2023). The Taguchi method used in this research has an effect on economic parameters, can reduce losses by utilizing process variability reduction. DoE techniques can eliminate undesirable impacts on the system, without eliminating the causes of these impacts.(Falcone et al., 2003).

Although these studies contribute valuable insights to their respective domains, they attempt to combine methodologies, including Quality Function Development (QFD), House of Quality (HOQ), and Kansei methods. Combining these approaches, along with distributing questionnaires, aims to provide a comprehensive understanding of people's needs and preferences, ultimately guiding the development of optimal designs.

II. METHODS

This research design has a process and stages in achieving its objectives. Where in this process there is a framework for the system in this research. The flow diagram of this research is as in Figure 1.

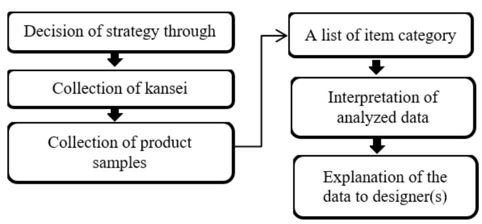

Figure 1. Research Framework

This stage is a step to obtain decision of strategy through QFD in figure 1. In QFD, quality control of a product is carried out based on consumer desires and needs. Quality Function Deployment (QFD) for developing quality designs that aim to satisfy consumers and then translating consumer demands into design targets and main points of quality assurance for use throughout all stages of production. House of Quality (HOQ) tool that supports the QFD method by using a matrix that relates customer desires to design steps and compares design steps so that practitioners can concentrate on the most important and valuable characteristics.(Dian, 2021). Researchers use this method to obtain the best feature results.

In the Collection of Kansei Engineering process in figure 1, the stages of the researcher carrying out the process start from interviews with the Indonesian people, direct interviews with the general public in Indonesia, Kansei Engineering groupings obtained from the market research stage and interviews with the people in Indonesia, the next stage is determining 5 Kansei Engineering matches. with the results. research and interviews, the next stage is to distribute questionnaires by providing design options according to the predetermined Engineering Kansei.

In the process of collecting product samples in figure 1, researchers used the Kansei-Taguchi and Kansei engineering methods, which are methods that can translate customer feelings and images of a product into design elements. Kansei engineering is also called product development based on customer desires and needs. The Kansei method makes it very easy for researchers to carry out designs to collect consumer needs based on consumers' emotional or psychological orientation. Kansei products are not expensive and high class products. So the use of the Kansei engineering method is a suitable way or method for developing a product or product design. Kansei engineering is also a method that translates opinions about consumer tastes into living design components known as Kansei engineering. This method was formulated in the 1970s by Mitsuo Nagamichi. The main focus of this method is to get the best design according to the specified Kansei Engineering. Kansei Engineering specified easy to use, adjustable lights, affordable price, modern design, and high technology. For the five Kansei Engineering determined from QFD results, as well as from the marketplace, both descriptions and reviews, the focus of smart table lamp users in Indonesia is in line with the five selected by Kansei Engineering. Of the five, Kansei Engineering also supports the Taguchi method, in this research using an orthogonal array of 3 levels, 3 parts, and L9. After carrying out an orthogonal array simulation of 3 levels, 3 parts, and L9 using Minitab, the following calculation results were obtained.

Table 1. Simulation Results

	Factor/Part		
No	**A**	**B**	**C**
1	1	1	1
2	1	2	2
3	1	3	3
4	2	1	2
5	2	2	3
6	2	3	1
7	3	1	3
8	3	2	1
9	3	3	2

After carrying out calculations and simulations in Minitab, we obtained an example of a design that would be created using the orthogonal array method. The orthogonal array applied in this research is attached as follows.

Figure 2. Array Ortogonal. Atas = top (A), tengah = middle (B), bawah = bottom (C)

After the orthogonal array is created, the next stage is to create a design according to the orthogonal array. In this study, the researcher used an L9 orthogonal array, in figure 3, the designs to be created totaled 9 images.

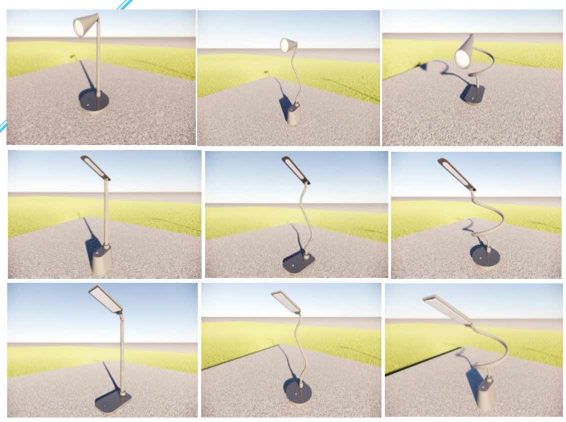

Figure 3. Create 9 visual images

The final stage is to create a designer sketch for each kansei word that has been created in accordance with the analysis results in Minitab using the Taguchi method. In the Taguchi method there are 3 types of characteristic qualities, including Larger is better, Smaller is better, Nominal is better. To see the characteristics of an experiment, the Signal to Noise Ratio (SN Ratio) is carried out.(Wulandari et al., 2016) From each quality characteristic of the SN Ratio we can see the following:

1. Larger is better

It is a characteristic of quality, the greater the value, the greater the value the best, because it is susceptible to infinite and non-negative values. As for the equation

The formula for the SN Ratio can be seen from the equation below:

$$SN\ Ratio = -10\ Log\ [MSD] = -10\ log\ [1/\ xi(j)^2] \qquad (1)$$

MSD = Mean squared deviation
$xi(j)$ = i^{th} experimental value on the j^{th} response

2. Smaller is better

It is a quality characteristic that the smaller the value, the better value, because the limit value is 0 and non-negative. The formula equation for the SN Ratio can be seen from the equation:

$$SN\ Ratio = -10\ log[MSD] = -10\ log[xi(j)^2] \qquad (2)$$

3. Nominal is better

It is a quality characteristic that the value that gets closer to the target is the desired value, because the target value is not zero and is free. The formula equation for the SN Ratio can be seen from the equation below:

$$SN\ Ratio = 10\ log[MSD] = 10\ log[xi(j) - m^2] \qquad (3)$$

m = specification target value

In this study, "larger is better" is used for the analysis of the SN ratio.

III. RESULTS AND DISCUSSION

3.1 Preparation of Requirements Design Matrix (How's) and Correlation Matrix

Technical characteristics will be formed to meet customer needs. In this case, the technical characteristic attributes (How's) are obtained from the results of distributing questionnaires that have been carried out. Several technical characteristics will be targeted for product development priorities, for example material, automatic on/off, minimalist design, medium size dimension, adjustable lamp, high-sensitivity sensor. Correlation that describes the relationship between technical characters is marked with a positive sign (+).

Correlations	
Positive	+
Negative	−
No Correlation	

Direction of Improvement	
Maximize	▲
Target	◇
Minimize	▼

Relationships	
Strong	●
Moderate	○
Weak	▽

Figure 4. Requirements Design Analysis (How's)

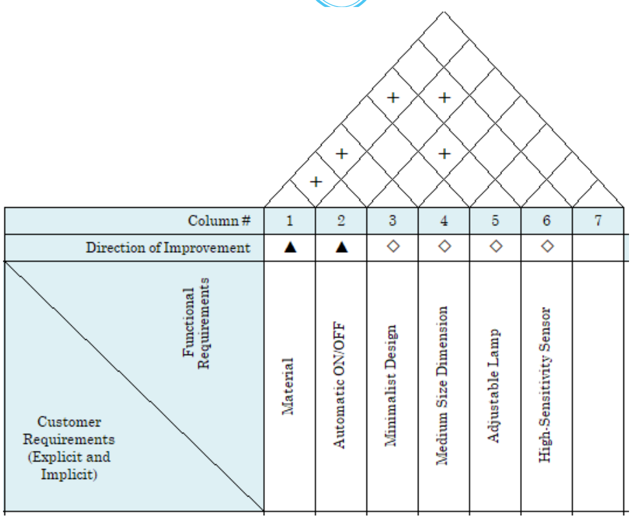

Figure 5. Correlation Matrix

3.2 Preparation of Relationship Matrix and of Interest Matrix (Technical Importance Rating)

A relationship matrix is a table created to identify the relationship between customer needs and the characteristics of the results of distributing questionnaires that meet those customer needs. The relationship matrix can be seen in figure 13 which consists of a weak relationship with a value of 1 (∇), moderate relationship with a value of 3 (O), and strong relationship with a value of 9 (●).The results of the technical importance matrix describe the value weight of each technical response related to customer needs. This Technical Importance Rating is obtained by multiplying the relationship value by the level of importance to customers (Importance to Customer) for each customer need (Customer Requirements) as a whole.

Relative Weight	Customer Importance	Maximum Relationship	Functional Requirements / Customer Requirements (Explicit and Implicit)	Material	Automatic ON/OFF	Minimalist Design	Medium Size Dimension	Adjustable Lamp	High-Sensitivity Sensor
17%	4	9	Low Energy Consumption		●				○
13%	3	3	Affordable Price	▽	▽	○	○		
13%	3	9	Highly durable product	●	○		○	▽	
17%	4	9	Modern Design	○	●	●	▽	○	
17%	4	9	Easy to Use	○	○	▽	○	●	●
22%	5	9	Hi-Tech Feature	○	●			○	●

Figure 6. Relationship Matrix

Target	Strong and durable up to 5 years	Low energy consumption	Unique, modern and timeless design	Easy to carry and moveable	Adjustable as needed	Sensor sensitivity 0,5 second	
Max Relationship	9	9	9	3	9	9	
Technical Importance Rating	300	613	213	147.8	287	404.3	
Relative Weight	15%	31%	11%	8%	15%	21%	
Weight Chart							

Figure 7. Technical Matrix

The results of the easy-to-use Kansei Engineering simulation using the Taguchi method in Minitab were analyzed using a total of 50 respondents. A total of 50 respondents were identified, referring to individuals interested in purchasing and those who already own a smart desk lamp. The resulting predicted values are as follows. The S/N ratio values obtained in the Kansei easy to use language and the image results obtained in Kansei easy to use language are based on the highest S/N ratio ABC, namely 222 with a design as below:

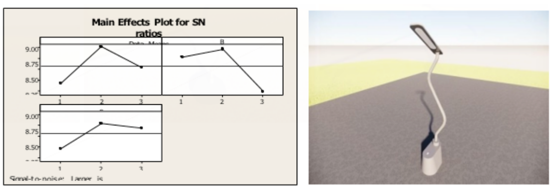

Figure 8. S/N Ratio for the "Easy to Use" and Visual 222

The results of the Kansei adjustable lamp language simulation using the Taguchi method in Minitab by analyzing a total of 50 respondents, the resulting predicted values are as follows. The S/N ratio values obtained for the Kansei adjustable lamp, and the image results obtained on the Kansei adjustable lamp are based on the highest S/N ratio ABC, namely 322 with a design as below:

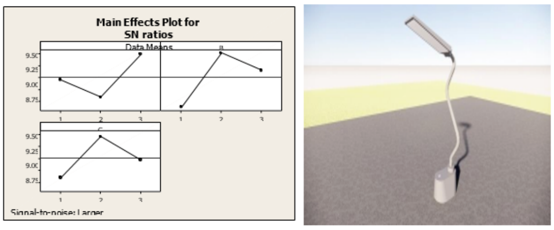

Figure 9. S/N Ratio for the "Adjustable Lamp" and Visual 322

The results of the Kansei affordable price language simulation using the Taguchi method in Minitab by analyzing a total of 50 respondents. The resulting predicted values are as follows. The S/N ratio values obtained in Kansei affordable price, and the image results obtained in the Kansei affordable price language are based on the highest S/N ratio ABC, namely 321 with a design as below:

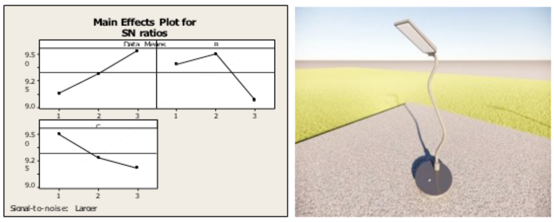

Figure 10. S/N Ratio for the "Affordable Price" and Visual 321

The results of the Kansei modern design language simulation using the Taguchi method in Minitab by analyzing a total of 50 respondents. The resulting predicted values are as follows. The S/N ratio values obtained in the Kansei modern design language, and the image results obtained in modern Kansei Engineering design are based on the highest S/N ratio ABC, namely 122 with the design as below:

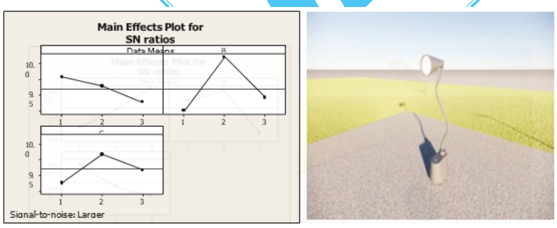

Figure 11. S/N Ratio for the "Modern Design" and Visual 122

The results of the Kansei Hi-Tech language simulation using the Taguchi method in Minitab by analyzing a total of 50 respondents. Following the result of QFD, the highest value of the Customer Requirements calculation is hi-tech with a value of 21.7%, while the second highest value is modern design with a value of 17.4%. Meanwhile, there is no significant difference between the meaning of the "Hi-Tech" Kansei with other Kansei Engineering. It can be observed that from the combination of all methodologies, including QFD, HOQ, Kansei Engineering, and Taguchi, hi-tech is the best design as it has the optimal values derived. The S/N ratio values obtained in the Kansei Hi Tech language and the image results obtained in Kansei hi-tech language are based on the highest S/N ratio ABC, namely 311 with a design as below:

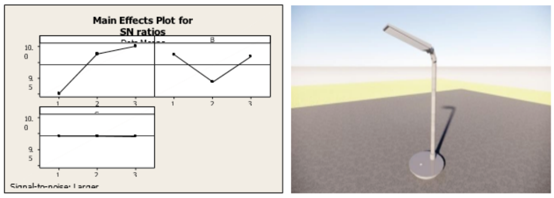

Figure 12. S/N Ratio for the "Hi-Tech" and Visual 311

IV. CONCLUSION

Using QFD, HOQ, Taguchi Method, and Kansei Engineering, this research developed an optimal smart desk lamp. Key customer priorities are high-tech features with value (22%) and modern design (17%). Essential features include adjustable brightness, with technical priorities being automatic ON/OFF (31%), high-sensitivity sensor (21%), and material (15%). These findings ensure the lamp aligns with customer needs.

The Taguchi method using Kansei Engineering produces optimal designs, The five Kansei Engineering that have been created are Kansei easy to use, adjustable lamp, affordable prices, modern design, and hi tech. hi tech using a distance sensor, if object is detected the light will automatically turn on, if object is not detected the light will automatically turn off. Based on the QFD questionnaire and design using Kansei Engineering, one best design was obtained, namely hi-tech. The design consists of 3 parts, namely the top, middle and bottom. At the top, the slim rectangular shape is preferable with lights position in the middle. Pole position is round, upright position. At the bottom, it has a circular shape. The QFD, HOQ, and design results were obtained from Indonesian respondents.

In further research it can be developed even better by using other Kansei Engineering. The integration of QFD, HOQ, Taguchi and Kansei engineering methods can be applied to other cases such as sleeping lights. And in further research it can be developed even better by creating the best design from all Kansei languages, which can be used with the SWOT and AHP methods.

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