

DESIGN OF LIGHTBULB REPLACEMENT TOOLS USING KANO AND TRIZ MODEL

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Abstract

Lights are the most common electrical product and are often found in households. One type of lamp that are widely used in general is the Light Emitting Diode (LED) lamp. The use of this type of lamp has a life span of between 50,000-100,000 h and low electrical power between 3-10 Watts. Product improvement can be a medium to evaluate its effectiveness at a certain time. Based on this, it is necessary to make the correct design so that it will be able to meet the needs and desires of consumers. In this study, 2 product design methods were used, namely the Kano and *Teoriya Resheniya Izobretatelskikh Zadatch* Model (TRIZ). The subjects of this study were users of light bulb replacement tools in the parippung area of bone district, South Sulawesi. The total population of 66 people using the Slovin method with a confidence level of 90%, the sample obtained was 40 respondents. The result of this research are Based on the Kano Model calculation, 8 repair attributes are obtained. The TRIZ method, then uses the formed attributes to be processed into the TRIZ contradiction. As the result, this method can increase the comfort levels, and decrease the musculoskeletal disorders.

Keywords: Light Bulb, LED, Design, Cano, TRIZ

Introduction

Lights are the most common electrical product and are often found in households (Hutasuhut *et al.*, 2019; Kumar *et al.*, 2019). One type of lamp that is widely used is the Light Emitting Diode (LED) lamp. The development of LEDs in Indonesia happened very quickly, and the lighting consumption usage of LEDs increased approximately 500 million units from 2013 to 2014 (Revantino *et al.*, 2018). LEDs are part of environmentally friendly lighting products and can save energy by 80% compared to other types of lamps (Lathifah and Widyastuti, 2018). LED lamps have a lifespan of between

50,000 and 100,000 h, and they require low electrical power between 3 and 10 watts (Faridah and Umar, 2018). With the advantages of LED lamps, their use has become extremely popular in the community.

Each product has a time period in which it will expire, resulting in replacement with a new, similar product. Improperly doing any work will increase the risk of health problems (Svendsen *et al.*, 2020). Understanding the correct work procedures can help improve job security and reduce health complaints (Sanjog *et al.*, 2019; Kurnia and Sobirin, 2020).

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In general, lights are placed on the ceiling of a house, and there are many ways to replace them. The process of replacing the lamp is usually carried out in a non-ergonomic way, such as using a table or chair as a medium to reach the ceiling. As for the lamp replacement aids that are currently sold on the market, a re-evaluation is needed to determine their level of effectiveness. Based on this problem, a lamp replacement tool was redesigned with the aim of increasing work ergonomics and productivity.

Prakosa and Tontowi (2010) conducted research on lamp replacement devices with high customer satisfaction results. However, there was a weakness in such tools, as they tended to have slippery handles that hindered gripping the lamp being replaced. Product development is useful for increasing demand and prices (Maestre and Granero, 2018). According to Purnomo *et al.* (2014), a product is said to be successful if it is able to meet consumer needs. Product improvement can be a way to evaluate a product's effectiveness at a certain time. Therefore, it is necessary to make the correct design so that the product will be able to meet the needs and desires of consumers (Haryono and Bariyah, 2014).

In this study, two product design methods were used, namely the Kano and Teoriya Resheniya Izobretatelskikh Zadatch (TRIZ) models. The Kano Model is a product development process for new ideas or concepts to increase customer satisfaction (Violante and Vezzetti, 2017; Ma *et al.*, 2019). The idea is then used as the basis for the concept of improving the product design being studied. After the design idea is fulfilled, a solution analysis is carried out using the TRIZ method. The design concept in the TRIZ method utilizes design contradictions to obtain the best solution for the product. The integration of these two methods can further improve the design results for new products (Hartono, 2016). The integration of these two methods has been carried out in various studies, such as online marketing campaigns, customer satisfaction analysis, etc. (Hartono, 2016; Huang and Tsai, 2017; Shahin *et al.*, 2017). The use of this integrated method is expected to make new product designs more ergonomic, effective, and productive for consumers.

Materials and Methods

Research Subjects and Object

The subjects of this study were users of light bulb replacement tools in the Parippung area of the Bone district, South Sulawesi, who have a productive age of 20-45 years, are male or female, and are housewives, students, or employees.

The total population of 66 people was selected using the Slovin method, with a confidence level of 90%, and the sample obtained was 40 respondents (Taifa and Desai, 2016). The object used is a light bulb replacement tool aimed at making it easier for consumers to replace damaged light bulbs. One of the components featured in this tool is that it has a grip regulator on the side of the pole to assist with replacing the light bulb. In addition to these functions, this tool is able to reach or remove lights in every corner, and it can also be used to clean the ceiling of the house.

Research Procedure

a. Preparation Step

At this stage, research preparation was carried out, consisting of equipment, product, and data collection preparation. Equipment preparation was done by preparing the tools used in the research process. The preparation for making products was done by purchasing old equipment and preparing the tools used to make the new product. Meanwhile, the preparation for data retrieval involved preparing stationery, a musculoskeletal disorder level questionnaire, and a comfort questionnaire.

b. Data Collection

The data collection stage was carried out by performing interviews and distributing questionnaires. Interviews were conducted to determine the process of using a lamp replacement device, and the interviews related to the variables required for the Kanoing concept. Meanwhile, the questionnaires were used to record comfort levels and musculoskeletal disorders with the Nordic Body Map.

c. Designing Step

The product design process was carried out using the Kano method, followed by the TRIZ method. The concepts of the Kano and TRIZ methods can be explained as follows.

Kano Mode

The Kano model is a method of product development based on consumer satisfaction (Ma *et al.*, 2019). This study aims to design a product for replacing light bulbs. All quality elements related to light bulb replacement were identified, after which the questionnaire was formulated based on the Kano model and addressed to the respondents.

The types of questions included in the questionnaire contradict each other, such as determining what respondents think when a feature is not made (negative) and what they think when the feature is made (positive). In the evaluation stage,

the distribution of the questionnaire results was translated into a Kano evaluation table. Negative questions were classified as dysfunctional, and positive questions were classified as functional. The results from the Kano model evaluation table were entered into the formula for calculating the Customer Satisfaction Coefficient (CSC; Maatita and Lawalata, 2017). The CSC shows the respondents' level of satisfaction with, as well as the perceived importance of, a product feature, and this can be seen in Figure 2, which depicts a Kano model diagram (Llinares and Alvaro, 2011; Taifa and Desai, 2016; Maatita and Lawalata, 2017).

TRIZ Method

TRIZ method is used in product design and development to solve problems. Each problem has a specific method for solving it. The effectiveness of use is adjusted to the needs. In addition to selecting methods, determining the solution becomes a new problem that must be resolved. The TRIZ method is a complex problem-solving method that provides effective solutions (San, 2016). In general, solving a problem is carried out by following the flow of defining the problem, identifying the root of the problem, collecting solutions, implementing solutions, and evaluating. This strategy is standard for solving problems. However, in solving a fairly complex problem, it is not uncommon for the solutions to create new problems or contradictions (Mann, 2001; San, 2016). Therefore, TRIZ is a tool used to solve these contradictions.

The first stage in TRIZ is to generalize the problem using several TRIZ analysis tools, such as function analysis, cause and effect analysis, or trimming. The problems that are generalized become a collection of problems that have been translated into the TRIZ language, including engineering contradictions, physical contradictions, function models, and substance-field models. After obtaining the translated problem model, TRIZ helps solve problems using tools such as the Contradiction Matrix and the System of Standard Inventive Solutions. The last step is to provide a more detailed explanation based on the solutions given, and these

solutions are seen in the 40 Inventive Principles and 76 Standard Inventive Solutions. In this research, the selection and implementation of the best solutions were carried out (Altshuller, 2007; San, 2016).

Difference Tests and Hypotheses

A difference test was performed using different tests with the same subject, where the subject used the old tool and the new tool. The difference tests measured the decrease in

musculoskeletal disorders and the increase in the level of comfort. The hypotheses of reducing complaints and accelerating processing time were as follows:

Complaint Decrease Hypotheses

- a. $H_0: \mu_1 = \mu_2$: There was no decrease in the level of complaints when using the old tool compared to the new tool.
- b. $H_1: \mu_1 > \mu_2$: There was a decrease in the level of complaints when using the old tool compared to the new tool.

Comfort Increase Hypotheses

- a. $H_0: \mu_1 = \mu_2$: There was no increase in the level of comfort when using the old tool compared to the new tool.
- b. $H_0: \mu_1 < \mu_2$: There was an increase in the level of comfort when using the new tool compared to the old tool.

Results and Discussion

Voice of Customer Identification

The research design was based on the voice of the consumer. This process was carried out by distributing questionnaires to consumers in accordance with the research criteria. The questionnaires were distributed to 40 respondents, divided into 42.5% male respondents and 57.5% female respondents. All the respondents were between 20 and 45 years old and had previous experience changing lamps.

Kano Model Analysis

The Kano model aims to analyze consumer voices by using a functional and dysfunctional questionnaire. The CSC calculation is part of determining the Kano category using Blauth's formula (Maatita and Lawalata, 2017). The CSC value and the results of consumer voice identification obtained 11 attributes, as shown in Table 1.

The following formula was used to calculate the CSC, with SI representing the satisfaction index and DI representing the dissatisfaction index (Kano *et al.*, 1984; Matzler and Hinterhuber, 1998)

$$SI = \frac{A+O}{A+O+M+I} \quad (1)$$

$$DI = \frac{M+O}{A+O+M+I \times (-1)} \quad (2)$$

The results of the recapitulation of the CSC calculations in Table 1 were used for the application of the design, with the following conditions:

- a. The Neglected category is indifferent because it will not increase customer satisfaction

Table 1. CSC Value and Kano model Category

Kode	Product Attribute (Kode)	SI	DI	A+M+O	I+R+Q	Category
X1	Can grip different sizes of lamps	0,19	-0,2	9	31	I
X2	The grip is not easy to damage the lamp	0,5	-0,6	30	10	M
X3	Strong gripping light	0,12	-0,5	19	21	M
X4	Light and strong stick	0,46	-0,7	28	12	O
X5	The stick is comfortable in the hand	0,53	-0,6	30	10	O
X6	The size of the stick can reach the platfon	0,33	-0,3	19	21	I
X7	Product way is easy to use	0,3	-0,7	30	10	M
X8	The stick can reach every corner	0,32	-0,6	24	16	M
X9	Multifunctional tool	0,63	-0,3	30	10	A
X10	Long lasting product	0,59	-0,5	28	12	O

Table 2. TRIZ analysis

Atribut	Improvement parameter	Worsening parameter	No. solution	Note	Sulotion on Product
X2 and X3	13. Stability of the object	16. Durability of Non-Moving Object	39, 3, 35, 23	Local Quality (#3), Parameter Change (#35)	Grip dimensions (# 3), PLA Plastic Material (# 35)
X4	1. Weight of Moving Object	12. Shape	10, 14, 35, 40	Composite Material (#40)	Aluminium
X5	19. Use of Energy moving object	10. Force	2, 16, 26, 21	Taking Out (#2)	The stick can be assembled into 2 parts
X7	11. Stress or Pressure	3. Length of Moving object	10, 35, 36	Preliminary action (#10)	Place the loop on the stick grip
X8	5. Area of Moving Object	22. Loss of Energy	15, 17, 30, 26	Dynamics (#15)	Disassemble pairs of sticks with a nested doll system
X9	26. Quantity of Substance	39. Productivity	3, 13, 27, 29	Local Quality (#3)	Ceiling cleaner
X10	15. Durability of Moving Obejct	39. Productivity	14, 17, 19, 35	Parameter Change (#35)	PLA aluminum and plastic material

regardless of whether the attribute is present. The X1 and X6 attributes belonged to this category; thus, these attributes were not applied to the design.

b. The Must-Be category is for basic attributes that a product must have; therefore, the attributes that fall into this category must be applied to the design. The X2, X3, X7, and X8 attributes belonged to this category.

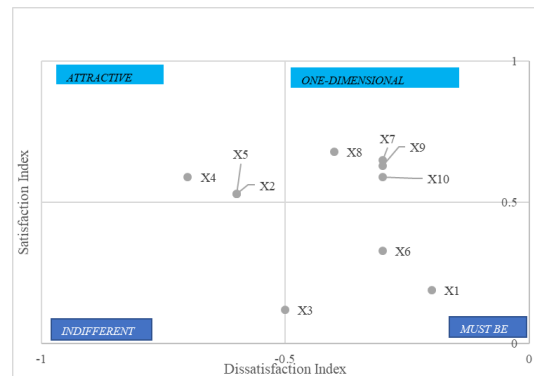
c. The One-Dimensional category includes attributes that will provide consumers satisfaction if they exist or disappointment if they do not exist. The X5 and X10 attributes belonged to this category.

d. The Attractive category includes attributes that will have a very positive effect if they are applied; however, they will not have a negative effect if they are eliminated. The X9 attribute belonged to this category.

Based on the SI and DI values, the level of customer satisfaction with the application of the attributes is shown in Figure 1.

TRIZ Analysis

The attribute selection results were based on the Kano analysis, and then a TRIZ analysis was performed to carry out the design. The TRIZ method was used in this study to analyze the proposed design solutions. Basically, the stages of this

**Figure 1. Scatter Diagram Kano Model**

method are in the contradiction matrix, which contains 40 principles. The matrix will form 39 inventive solutions, with the solution results adjusted to the matrix results. This study used eight attributes for designing the new product, as seen in Figures 2(a), 2(b), 2(c), and 2(d).

Table 2 is explained as follows:

a. The X2 and X3 attributes were combined into a grip physical form attribute. If these attributes were added, the object's stability would increase, but its durability would decrease. The proposed inventive solution was based on a contradiction

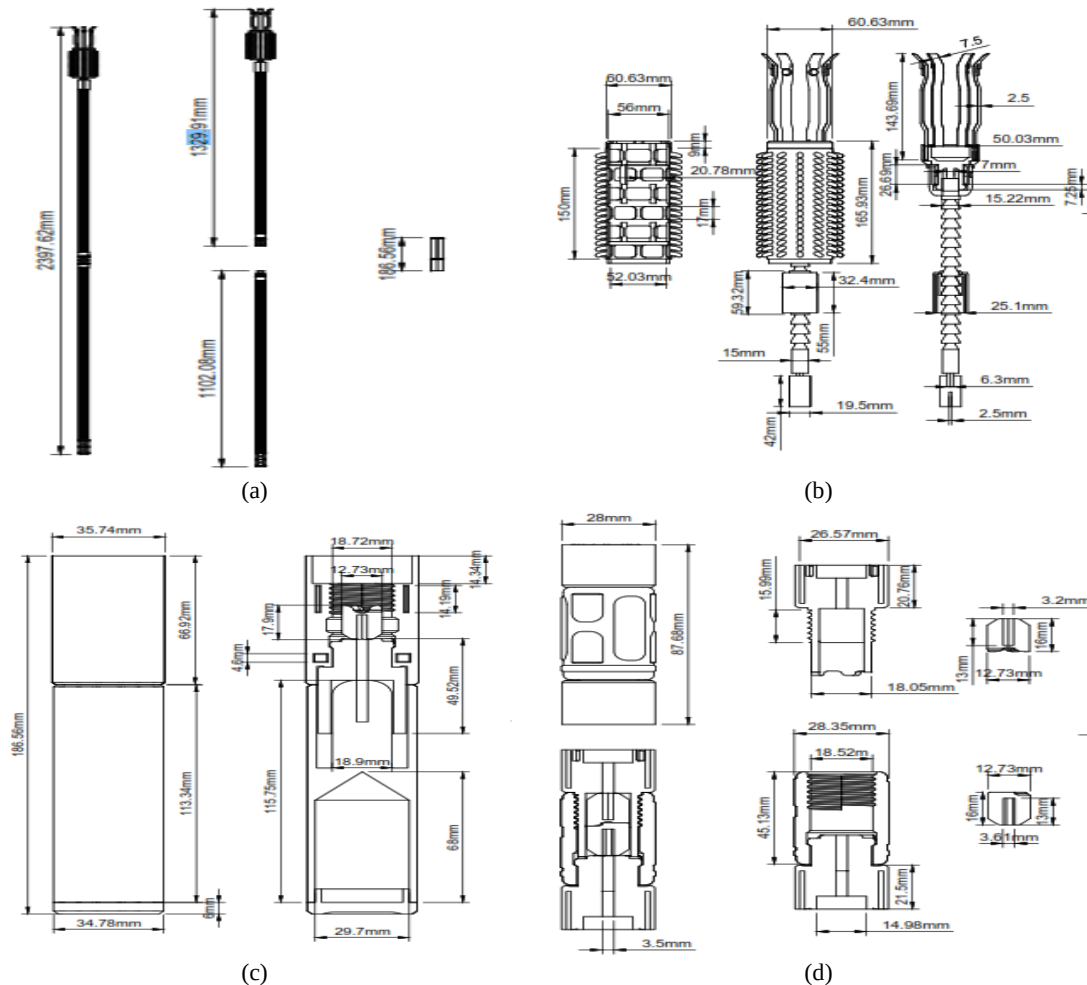


Figure 2. a) Proposed lamp replacement; b) Head lamp replacement; c) Modular handle; d) Connector

matrix of four existing solutions, in which two solutions were applied to the design. The design solution chosen was Local Quality (#3), and it was applied in the form of a grip dimension. The grip dimensions can be seen in Figure 3, and the Parameter Change (#35) design solution was applied in the use of a PLA plastic material with rubber on the outside of the grip.

b. If the X4 attribute were added, the weight of the product would decrease, but the shape would become complex. The proposed inventive solution was based on a contradiction matrix, and from the four existing solutions, one solution was applied to the design. The solution chosen was using a Composite Material (#40) in the stick design. The design material was made of aluminum, with a diameter of 25 mm, and each stick connector had a plastic material that served to maintain the stick's strength.

c. If the X5 attribute were added, the energy expended during the work process would decrease,

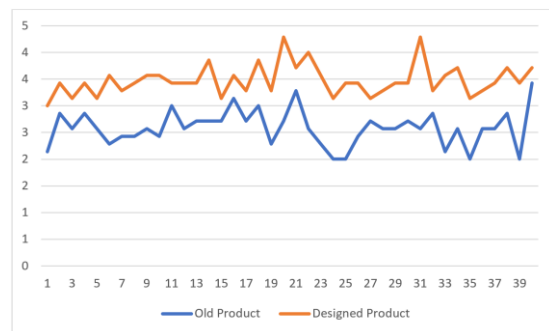


Figure 3. Comparison of comfort levels

but the force would increase. The proposed inventive solution was based on a contradiction matrix, and from the four solutions, one solution was applied to the design. The chosen design solution was Taking Out (#2), and this was implemented by creating a stick that could be assembled from two parts (Figure 2(a)).

d. If the X7 attribute were added, then the stress or pressure would decrease, but the product height would increase. The proposed inventive solution was based on a contradiction matrix, and of the three solutions given, one solution was applied to the design. The design solution chosen was a Preliminary Action (#10), and this was applied by creating a grip swivel at the bottom of the stick so that both hands were not needed to rotate the stick (Figure 2(d)).

e. If the X8 attribute were added, then the reach would be increased, but the energy expended would increase. The inventive solution proposed was based on the contradiction matrix of four possible solutions, with one solution applied to the design. The chosen design solution was Dynamics (#15), and it was applied by creating a stick assembly with a nested doll system (Figures 2(a) and 2(d)).

f. If attribute X9 were added, the number of functions would increase, but productivity would decrease. The proposed inventive solution was based on a contradiction matrix, and from the four solutions given, one solution was applied to the design. The design solution chosen was Local Quality (#3), and it was applied to the head of the stick by creating a position below the ball grip for a ceiling cleaner (Figure 2(b)).

g. If the X10 attribute were added, the product durability would increase, but productivity would decrease. The inventive solution proposed was based on the contradiction matrix of four possible solutions, with one solution applied to the design. The chosen design solution was Parameter Change (#35), and it was applied by using aluminum and plastic materials.

Product Testing

Testing was intended to identify the product design's level of benefit, and to gain valid results, the testing was performed by 40 respondents. The result were obtained by questionnaires of Nordic Body Map. The results would be positive if the design proved useful, met the users' wishes, and reduced work complaints. In this study, a difference test was conducted to determine the level of musculoskeletal disorders and the level of comfort.

a. Difference Test of Musculoskeletal Disorder Levels

The data in this test calculated the difference between the old product and the new product, as seen in Figure 4. The process was carried out by testing the level of musculoskeletal disorders between the old product and the new product. Musculoskeletal disorders can result in short-term to

long-term pain complaints; however, if they are not addressed, they will increase the negative impact that is felt. The measurement tool used was the Nordic Body Map (NBM). The scale used was No Pain (1), Slight Pain (2), Painful (3), and Very Painful (4). Figure 4 shows the difference in the levels of musculoskeletal disorders when using the old and new products. This research difference test used the Wilcoxon Signed Rank Test approach. The test results showed an Asymp. Sig. (2-tailed) value of $0.000 < 0.05$, which meant that there was a difference in use between the old product and the new product. Thus, the use of the new product can reduce the level of musculoskeletal complaints.

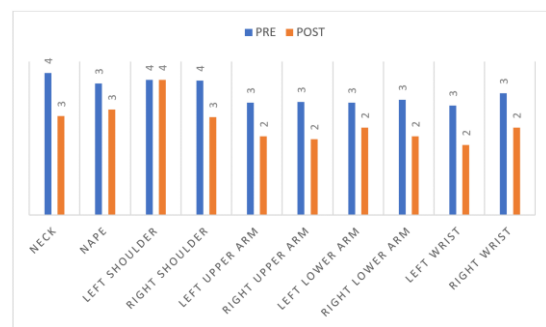


Figure 4. Comparison of musculoskeletal disorders

b. Testing Different Levels of Comfort

Testing the level of comfort aimed to determine the user's comfort when using the product. Forty respondents, who had been with the research since the beginning, filled out the comfort questionnaire after using the old and new products. This research difference test used the Wilcoxon Signed Rank Test approach. The test results showed an Asymp. Sig. (2-tailed) value of $0.000 < 0.05$, which meant that there were differences in the use of the old and new products. Thus, using the new product was more comfortable than using the old product. Figure 4 shows a graph of the comfort level of using the old and new products.

Conclusions

This study used two design methods, namely the Kano model to identify the attributes of improvement and the TRIZ method to analyze design solutions. Based on the Kano model calculations, eight repair attributes were obtained: the grip does not easily damage the lamp, strong in gripping the lamp, light and strong sticks, comfortable sticks in the hand, easy-to-use tools, sticks can reach horizontal and vertical positions,

multifunctional tools, and durable products. The TRIZ method then used the formed attributes to determine contradictions. Based on the prototype solution formed, a complaint test was carried out by comparing the old product and the new product. The results showed that the new lamp replacement prototype had lower levels of musculoskeletal disorders and a higher level of comfort compared to the old product.

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