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OPTIMIZATION OF ART CLEANING DEVICE BASED ON ELECTRONIC USER EXPERIENCE

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ABSTRACT
With the continuous growth of the number of artistic groups, the brush cleaning problem has gradually become the focus of the industry, which has led to a change in consumer demand for brush washing utensils. This study aims to analyze the shortcomings of existing brush washing utensils on the market and propose an optimized design scheme for automatic brush cleaning devices. Research methods: First, by collecting user evaluation data on online usage experience, the technical defects of current brush washing utensils and the tendency of user needs are identified. Subsequently, a KANO model questionnaire is used to conduct a sample survey of the target user group, and user demand indicators are extracted through data mining technology to clarify the direction of product function design. Research results: Guided by TRIZ theory, this study explores technical improvement solutions and resolves potential conflicts, and finally designs a brush washing utensil that can meet user needs. Research conclusion: The innovative brush washing utensil design integrates the characteristics of automation, efficiency and sustainability, effectively breaks through the limitations of traditional brush washers, and provides technical guidance for the design of future brush washing utensils.
Keywords: Brush cleaning device; KANO model; Optimal design; Sustainable tools.

1. INTRODUCTION

With the technology advancement and the increasing demand for user experience, automated cleaning equipment has become a hot research topic. The art world requires the use of various types of brushes in the painting process, which have a large amount of cleaning and a complex process. At present, the cleaning equipment on the market cannot meet the needs of users to clean multiple specifications of brushes at the same time. Most products are designed as open or completely open designs, which can easily cause stains to adhere to clothing. Wen Yaqi (2024) designed an automatic cleaning pen machine driven by a motor to rotate the pen holder; Yang Youxi (2021)designed a multi-purpose brush cleaner; Wang Shuangshuang (2025) designed a makeup brush cleaner. However, the protection measures for the pen holder and brush in the above design have not been fully considered. The entire cleaning process still requires manual participation, resulting in poor user experience. As an important auxiliary tool for artistic creation and daily writing, brush cleaning equipment has received widespread attention due to its optimized design, especially the growing demand in the art world. In the research of automatic cleaning devices. Hu Guang (2025) carried out the automation transformation of a certain product cleaning machine. In order to realize the automatic cleaning function of soybean milk machine, Wu Yanhua (2022) designed a crushing chamber with at least three sections. Han Fuqiang (2017) designed an automatic cleaning device for water tanks. The author analyzed the relationship between the pumping flow rate and the rotational speed of the device in a stable state, and introduced the main structure and working process of the cleaning device. Sun Xianming (2024) designed a pneumatic water stirring automatic vegetable cleaning machine. Current research mostly focuses on improving a single technology, lacking systematic optimization methods, and there has not been in-depth research on the integration of automatic cleaning and brush cleaning. This study adopts the KANO model and TRIZ theory, providing new perspectives and methods for equipment innovation and optimization.

In the early stages of the research, Python was used to crawl user reviews from Taobao shopping websites, conduct data analysis, and propose user evaluation tendencies and functional requirements for products. Subsequently, the KANO model questionnaire was used to survey the target users and summarize their main needs for brushing equipment. Through user model analysis and questionnaire surveys, the focus of product development was clarified. The Kano model mainly focuses on user needs and is an effective tool invented by Professor Yuzuru Nonaka (1984) studied the classification and prioritization of user needs at Tokyo Institute of Technology in Japan. The model analyzes the impact of satisfaction based on user needs and reveals the nonlinear relationship between product performance and user satisfaction. It divides needs into four types: basic, expected, excited, and undifferentiated, helping designers accurately grasp the true and necessary needs of users. At present, the KNAO

model is also widely used in product design. By investigating and analyzing customer satisfaction, it is possible to discover the unspoken needs of users deep inside their hearts

This study also applies TRIZ theory to describe and analyze existing products to resolve technical conflicts. The TRIZ theory provides a series of innovative design strategies and methods for resolving conflicts and contradictions in design. This theory was proposed by Russian scientist Genrich Altshuller (1996) and is currently widely adopted by many scholars in the fields of product functionality, design, and more. Previous research cases have shown that this combination method exhibits significant advantages in complex product design. Li Fenqiang (2023) applied TRIZ theory to improve the prototype product of the target patent and designed a shopping cart solution that is more suitable for elderly people. Chen Chuxiao (2022). used TRIZ theory to establish functional models and conflict resolution theory to optimize the design of ultrafiltration systems in the secondary effluent reuse process of sewage treatment plants. Wen Fei (2021) designed a pressure ear manual mixing cup by applying TRIZ theory. Du Mo (2018) used TRIZ theory to avoid the drawbacks of traditional washing machines and designed a new type of micro washing machine suitable for use in dormitories. Zhou Hongyu (2023) provided a new solution for the existing design of electric water heaters by using the OFD-TRIZ product design model and incorporating the fuzzy comprehensive evaluation method. Gao Honghe (2025) used AHP-QFD-TRIZ to discover and resolve the necessary contradiction between user demand for products and the lack of existing product technology in the market, and proposed design solutions to optimize product performance and enhance user satisfaction of pet grooming machines . Zhang Dan (2017) applied TRIZ theory to create a cleaning machine model for threaded food bottles. Jalil 2021) designed a portable electrolytic water cleaning device using the triz method. The combination of TRIZ theory and KANO model provides strong theoretical support for the optimization design of automatic brushing devices, which can grasp the product needs of users and design innovative, practical, and more comprehensive products.

2. RESEARCH FRAMEWORK

This study first targets the target user group and uses Python to crawl data using the keyword "brush cleaning tool" on the most popular shopping websites currently available, such as Taobao and Tmall, to classify and screen products sold on the market, analyze user experience evaluations, and extract potential product functional requirements. Conduct a KANO questionnaire survey among the target user group to calculate user satisfaction and dissatisfaction with product functionality, to further extract design themes and improvement directions for cleaning devices. Based on the Kano survey and Python analysis results, accurately locate the user's functional requirements for the products and the functions that need improvement and innovation. Using the TRIZ theory's material field model and physical contradiction analysis, and technical contradiction analysis, analyze the technical problems of the product and attempt to design a brush cleaning device with complete ideas and innovation that meets the user's needs. The specific research framework as below Figure 1 Research Framework.

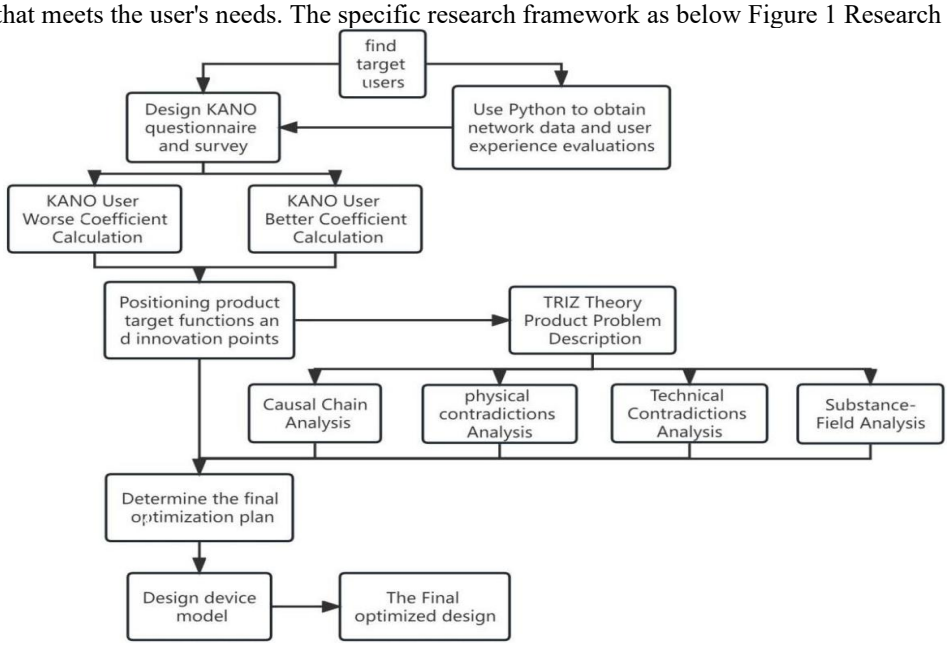


Figure 1 Research Framework

3. DATA COLLECTION AND ANALYSIS BASED ON PYTHON NETWORK

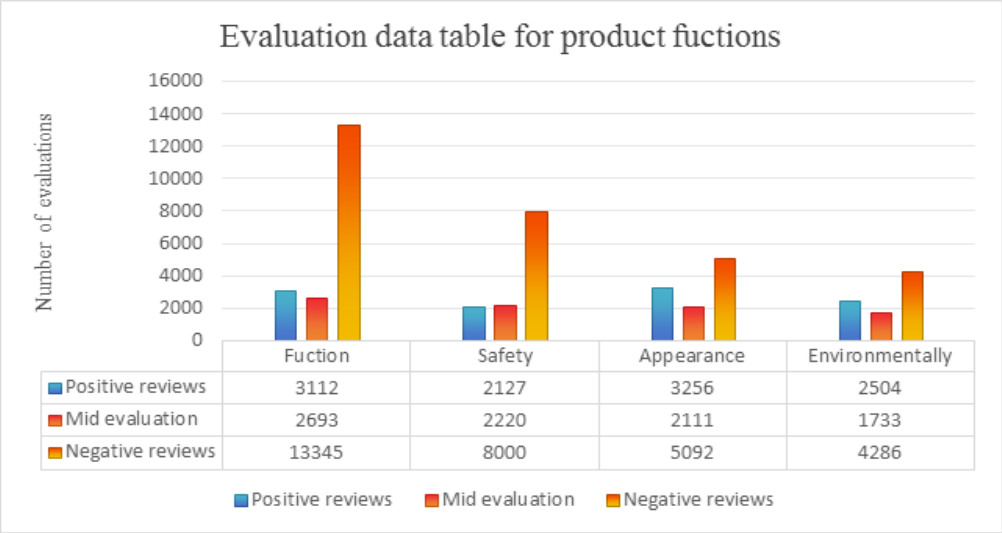
3.1 Comment Collection and Data Analysis

After searching for the keyword "brush washer" on Taobao and Tmall platforms, 46 representative brands including Liupintang, Feileyu, Mali, Deli, and Zhongsheng Painting Materials were successfully retrieved. These brands mainly sell five types of brush cleaning tools, including traditional porcelain bowls, stainless steel oil painting buckets, simple partition types, circulating water adding types, and folding water buckets, which constitute the mainstream product categories in the market.

In order to have a more comprehensive understanding of the market situation, we sorted these five types of products in descending order based on the number of comments, and crawled the top 10 product links from each type, obtaining a total of 50 links. Through data scraping, we collected 72732 evaluation data. After filtering out default positive and invalid evaluations, we collected 50479 valid evaluation data.

These evaluation data provide us with valuable information on the user's evaluation level, focus, and expected features of the current product. We categorize these evaluations into four categories based on vocabulary characteristics: product functionality, appearance, safety, and environmental friendliness, and further subdivide them into positive, medium, and negative reviews. The specific data organization results have been presented in Table 1 Product Function Evaluation Data Sheet. By analyzing these data in depth, we can gain a clearer understanding of user needs and pain points, thereby providing strong guidance for product iteration and innovation. These data not only help us optimize existing products but also provide an important reference for future product improvement and innovation directions.

Table 1 Product Function Evaluation Data Sheet



3.2 Extract Potential Functional Requirements

Recently, we have conducted in-depth data collection and analysis on popular brush cleaning products on the market. The results show that the mainstream brush cleaning products on the market still mainly use manual cleaning methods, and the degree of automation is generally low. This cleaning method is not only cumbersome, time-consuming, and labor-intensive, but most products are not compatible with various types of brushes, which undoubtedly increases the difficulty and inconvenience for users to use. Further user surveys show that users are most concerned about the functions of this product, followed by the safety, and then the appearance design and environmental friendliness. Based on user feedback, the performance of brush cleaning products on the current market is not satisfactory in these aspects. From the user evaluation chart, it is evident that there are a large number of negative reviews, which reflects a low level of user satisfaction with existing products and a high demand for product functionality.

Based on the above market research and user evaluation analysis, we have designed and conceptualized the product from the user's perspective, focusing on its cleaning function, portability, safety, and environmental friendliness during use. Our goal is to compensate for the functional deficiencies of existing products, meet user expectations for the product, and enhance the user experience. Overall, we hope to provide a more convenient, efficient, and safe brush cleaning experience through these improvement measures, meeting their cleaning needs during the painting process.

4. ANALYSIS AND DESIGN BASED ON KANO MODEL

4.1 User Positioning

To gain a more profound understanding of the needs and satisfaction of art students and artists aged 18 to 35 with brush cleaning devices, the study conducted a user-centered questionnaire survey. Through the carefully designed KANO questionnaire, we aim to capture the true voice and expectations of this core user group. Our target users are mainly young people who are full of vitality and brave enough to try new things. However, due to heavy work and learning tasks, they often do not have enough time and energy to properly clean their brushes.
In addition, they generally have a higher educational background and a sharper insight into environmental and health issues.
For artists, the brush is an indispensable tool in their creative process. When painting, they often need to replace different types of brushes, and cleaning these brushes becomes a tedious and time-consuming task. What is even more concerning is that improper cleaning methods may cause damage to the brush bristles or cracking of the brush stem, resulting in a waste of resources. Considering that professional artists often need to go out to sketch, they need a portable, efficient, and easy-to-use brush-cleaning device. However, existing washers in the market often struggle to meet these diverse needs simultaneously.
Therefore, this research is based on the actual needs of the target group, starting from four aspects: functionality, safety, environmental protection, and portability, to carry out product design concepts. We have identified eight key product features and conducted a detailed user survey on these features through the KANO questionnaire, aiming to provide users with a brush-cleaning device that truly meets their expectations. Through this method, we hope to provide artists with a more convenient function, efficientfunction, and environmentally friendly function brush-cleaning solution.

4.2 KANO Questionnaire Design

This study focuses on the topic of a fully automatic brush-cleaning device. The questionnaire includes eight functional requirements: automatic function, efficient cleaning, maintenance function, timing function, filtering function, detachable, battery storage function, and small volume. A KANO survey questionnaire was conducted, which set positive and negative questions for each function to test the user's attitude when the product has and does not have a certain function. The interviewed user selects the answer to the positive and negative questions from the five options of very satisfied, satisfied, reasonable, indifferent, and disliked. The assignment method is to score 1-5 points. The questionnaire format is shown in Table 2 Questionnaire Design Form.Table 2 Questionnaire Design Form

Question 1: Automatic, no manual involvement required during the cleaning process					
Please tick the answer you agree with√	Satisfied 5	Good 4	Deservedly 3	Indifferent 2	Dislike 1
What is your rating for having this feature：					
Without this feature, your review is:					

Table 3 Evaluation Criteria for the KANO Model

With / Without		Forward Problem				
		Satisfied	Good	Deservedly	Indifferent	Dislike
Inverse Problem	Satisfied	Q	A	A	A	O
	Good	R	I	I	I	M
	Deservedly	R	I	I	I	M
	Indifferent	R	I	I	I	M
	Dislike	R	R	R	R	Q
Notes	**A Charm type:** Users express surprise towards this feature, and their attitude is not affected when the feature is not available. **O Expectation type:** Users crave to have this feature, and when satisfied, their favorability increases. If not satisfied, it decreases. **M Essential type:** When users have this feature on the product, their attitude remains unchanged, otherwise their favorability decreases. **I No difference type**: Whether this feature is provided or not, user satisfaction will not change. **R Reverse type:** After providing this feature, the user's favorability decreases. **Q Suspicious type:** The forward and reverse answers to the same question are the same.					

5. NALYSIS OF KANO RESULTS

In this survey there are total of 320 questionnaires, 266 were valid and 54 were suspicious. The effective rate of the questionnaire was 83%. According to the Table 3 Evaluation Criteria for the KANO Model, analyze the obtained data. After removing suspicious responses, calculate the coefficient values of Better Worse for each function using a fixed formula, and then rank them from high to low based on the coefficient of product indicators to finally determine their demand attributes. The specific statistical results as below Table 4. And draw the analysis charts of Better and Worse coefficients, as shown in Figure 2. The standard formula for coefficient calculation is:

$$Better=(A+O)\div(A+O+M+I)$$

$$Worse=(O+M)\div(A+O+M+I)\times(-1)$$

Table 4 KANO Questionnaire Statistics Results

Category	Requirement	A	O	M	I	R	Better	Worse	Ranking	KANO
function Design	automatic	36.33	46.07	2.62	14.98	0	82.4%	-48.69%	4	O
	efficient	26.97	56.93	4.12	11.99	0	83.9%	-61.05%	2	O
Security Design	conservation	23.97	60.3	5.99	9.74	0	84.27%	-66.29%	1	O
	timed	32.96	41.95	8.61	16.1	0	75.19%	-50.75%	8	O
Environmental Design	filtered	26.22	54.31	7.49	11.99	0	80.52%	-61.8%	6	O
	removable	24.34	56.55	7.87	11.24	0	80.9%	-64.42%	5	O
Portable Design	electronic	24.72	58.8	6.74	9.74	0	83.52%	-65.54%	3	O
	small volume	27.34	51.31	4.49	16.85	0	78.65%	-55.81%	7	O

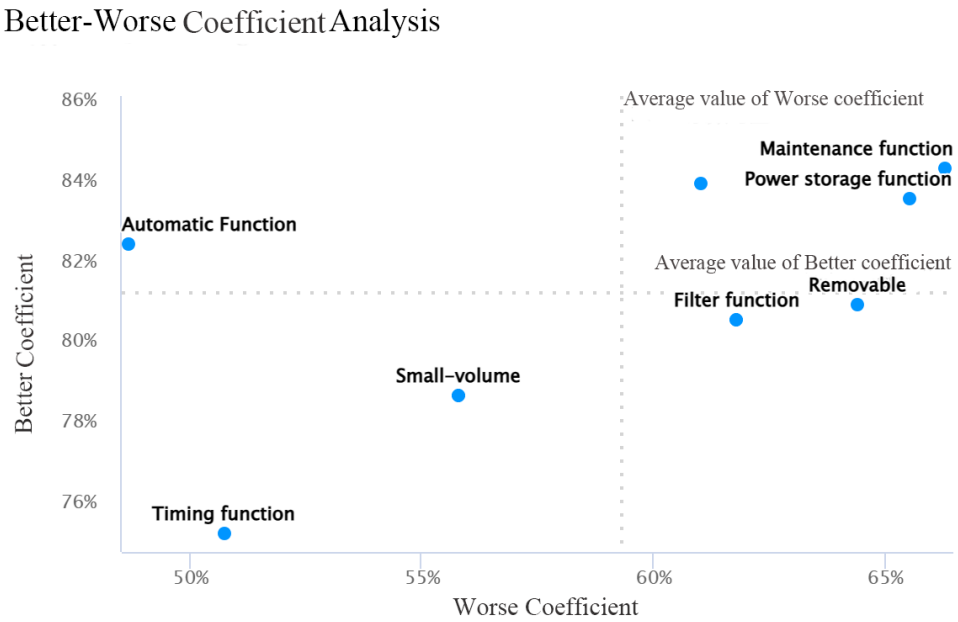


Figure 2 Better-Worse Coefficient Analysis

5.1 Lock Product Target Function

According to the results of this questionnaire, it was found that users hold expected attributes (O) for all 8 demand indicators of this product. These expected requirements, including automatic function, cleaning function, maintenance function, timing function, filtering function, disassembly function, battery storage function, and small size, constitute the long-term functional requirements characteristics of this brush cleaning device when competing with other similar products. To enhance user satisfaction and demand indicators for our product, continuous improvement must be made on these 8 features. If these needs cannot be met, user satisfaction may decrease accordingly.

Therefore, we must accurately grasp the user's demands for the product, and based on this, lock in the target functions and innovative points of the product.
By continuously optimizing and enhancing these expected features, we have the potential to make our brush-cleaning device stand out in the fiercely competitive market and meet user expectations.

6. PROBLEM ANALYSIS BASED ON TRIZ THEORY

6.1 Problem Description

After an in-depth investigation, it was found that the brush cleaning devices currently sold in the market mainly rely on manual operation, and their design is relatively simple. The cleaning process is both time-consuming and laborious. These products still have issues such as fragility, water leakage, and inconvenience in carrying, and the user experience is not ideal, which cannot meet the needs of the majority of users. For example, in the case of a multifunctional circular pen washer, the operation process requires the user to manually press the button after each cleaning to discharge sewage and refill it with clean water. Due to the emphasis on portability in the design, the overall size of the product is small, resulting in the limited capacity of the water bucket and narrow sink design. Only one small brush head brush can be cleaned at a time, which cannot meet the cleaning needs of various types of brushes. In addition, frequent manual operations not only increase the user's labor intensity, but may also lead to lost or damaged connections between the sewage collection box base, sink, and buttons, thereby causing water leakage problems.
In response to the above issues and user needs, this study proposes an automatic cleaning device for paintbrushes (Wang, 2020), aiming to meet the following design requirements:
Firstly, the device should have high functionality, which is the focus of optimization. Implement automated cleaning processes without the need for manual intervention to improve cleaning efficiency and adapt to a variety of different types of brushes.
Secondly, safety. The device should have a timing function and automatically shut off after cleaning to prevent damage to the paintbrush caused by excessive cleaning and ensure electrical safety.
Again, environmental friendliness is also an important factor we consider. The device should be designed with filtration and automatic circulation functions to ensure that the cleaning water can be recycled after filtration, reducing waste of water resources. At the same time, after multiple uses, the device should be easy to disassemble, clean internal impurities, and replace filters to meet environmental requirements.
Finally, the portability design is also a major highlight of this device. The device should have a power storage function, which can be used both indoors and outdoors after being fully charged, making it very suitable for outdoor sketching and other scenarios. In addition, by adopting a cylindrical design, we strive to minimize the footprint while maintaining the functionality of the device, making it easier to carry and store.

6.2 Problem Analysis

Using the system analysis method in TRIZ, classify the system functions of the brush cleaning device, focus on analyzing the interaction relationship between the internal system functions of the brush cleaning device, and identify the existing problems (Wang, 2022). The intermediate components in the device include a rotating plate, clamping holes, a processing box, an impeller, a micro water pump, and a collection box.
The products are brushes and impurities. The supersystem components of the device include a transmission system and a filtration system. By analyzing the functional model diagram, identify the reasons for the inconvenience in using the device, as shown in Figure 3 Functional Model. Firstly, while fixing the brush, the clamping hole can also cause compression and some degree of wear on the pen holder. Secondly, when the filtering system is insufficient, it can cause blockage of the micro water pump, making it unable to pump water or extract unfiltered dirty water, resulting in unclean brush cleaning.

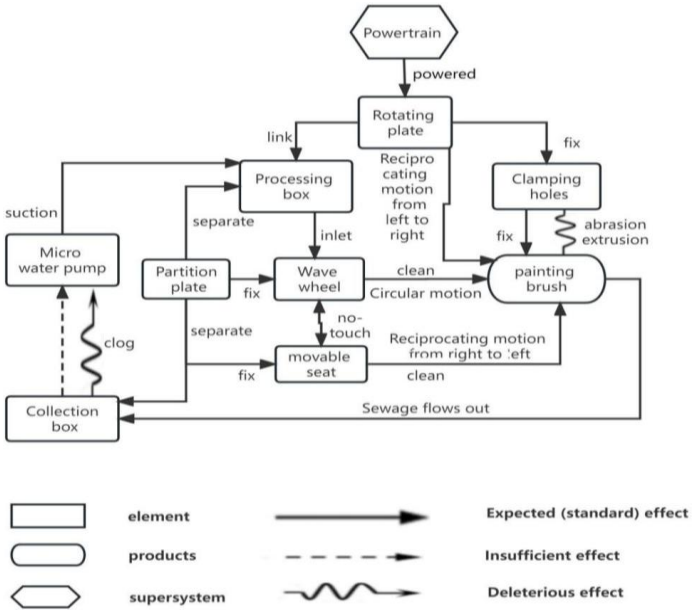


Figure 3 Functional Model

6.2.1 Causal Chain Analysis

This study used causal analysis to identify potential weak issues in the product and conducted reverse derivation analysis on technical issues to identify weak links in the design, which is the foundation for solving the problem. As shown in Figure 4 Reverse Derivation Analysis Diagram,

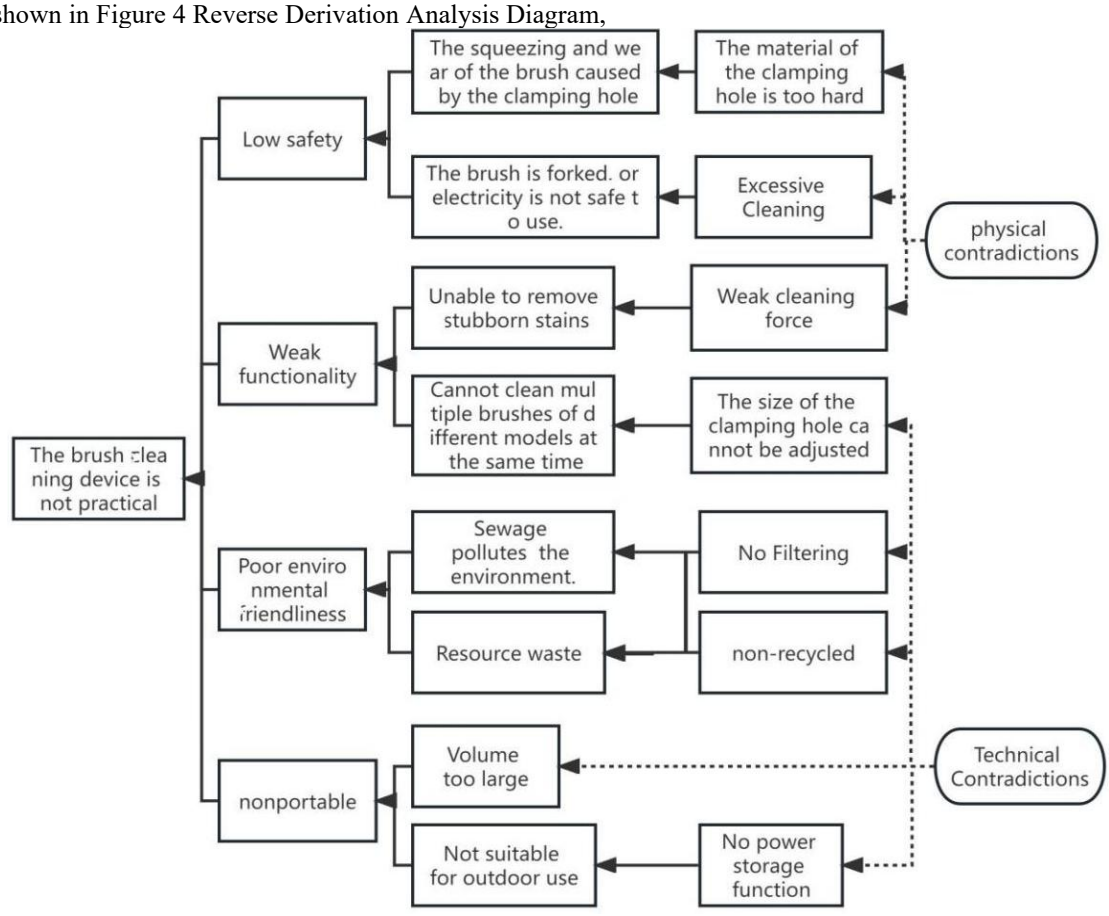


Figure 4 Reverse Derivation Analysis Diagram

6.2.2 Analysis of Physical Contradictions

Describe the problem of the brush cleaning device based on the physical contradiction analysis method in TRIZ's invention theory. According to Genrich Altshuller's interpretation of TRIZ theory, physical contradiction refers to the contradiction that arises within the same parameter due to different requirements, which is not conducive to ideal needs.

(1) If the cleaning device is nonremovable, the sealing effect of the device is good, and the cleaning process is more stable, but it is not conducive to regular maintenance and cleaning of the device; If the device is detachable, it is convenient to regularly clean and inspect the inside of the device, which can appropriately extend the service life of the device, but there may be instability.

According to the principle of separating the whole from the parts, separate the cleaning and treatment tank of the device from the sewage collection tank. Solution design: The interior of the processing box is divided into two cavities: the upper part is the processing box, and the lower part is the collection box. The outer shell of the processing box accommodates the collection box, and the inner wall of the processing box is in contact with the outer wall of the collection box. The processing box is completely in contact with the base of the collection box, forming a closed shape. It not only ensures stability and sealing during cleaning but also has a detachable function for regular maintenance and cleaning while enhancing the environmental friendliness and service life of the device.

(2) If the brush cleaning device has a power storage function, it is convenient for outdoor sketching and has better portability. However, the need to add a power storage tank will increase the volume and weight of the device, causing inconvenience in carrying; If the device does not have a power storage function, the utilization rate and portability of the device will decrease.

Separate the battery and brush cleaning device using the principle of spatial separation. Solution design: Change the plug to a USB interface, which can also be used outdoors to connect to a power bank. This not only reduces the weight and volume of the device but also enhances its practicality.

(3) If the cleaning effect of the product is strong, it can effectively clean stubborn stains on the paintbrush, but it is easy to cause the brush head to explode or split, or cause electrical safety hazards; On the contrary, the effect is not good.

The separation principle in TRIZ theory is applied to classify brush cleaning into two systems, ensuring the cleaning effect of the brush while avoiding damage to the brush head. Solution design: Moving seats are installed inside the fixed seats on both sides of the partition board, which can clean the brush through the reciprocating motion of the moving seats. The cross-sectional shape of the top of the moving seat is C-shaped, and rubber bristles are set on both sides of the outside. This not only effectively cleans stubborn stains in the deep part of the brush, but also softens the bristles, avoiding forking and hair explosion, thereby achieving efficient cleaning of the brush.

6.2.3 Analysis of Ideal Solutions

The most ideal solution is to enable the device to have high functionality, high safety, high environmental protection, and high portability at the same time. The second ideal solution is for the device to have high functionality, high safety, high environmental protection, and a certain degree of portability (Wang, 2022).

6.2.4 Technical Contradiction Analysis

Technical contradiction refers to the mutual exclusion of two parameters in a certain technical system, that is, when one parameter improves, the other parameter immediately deteriorates, forming a contradiction. Use this analysis method to describe the functionality, safety, and environmental friendliness of the brush cleaning device: From a functional design perspective, if the clamping hole design has a telescopic adjustment function, it can be suitable for different models and sizes of brushes. Traditional design schemes require manual tightening of nuts for adjustment, which will increase the preparation work before cleaning, resulting in increased labor costs for users and inconvenience. The improvement parameters and deterioration parameters extracted from them are the expansion and contraction adjustment function of the clamping hole and the increase in labor cost. By substituting them into the TRIZ conflict matrix, the corresponding invention principles are No.25, No.27, and No.34, as shown below in Table 5 Functional Design Improvement.

Table 5 Functional Design Improvement

Project	Specific Parameters	General Engineering Parameters	Corresponding Invention Principles

Improve parameters	Expansion and contraction adjustment function of clamping holes	No.38 Automaticity	No.25 Self-service principle No.27 Cheap substitutes No.34 Partial exclusion and regeneration principles
Deterioration parameters	Increased labor costs	No.37 The difficulty level of monitoring and testing	

As shown in Table 5, the improvement parameter of the device is No. 38, and the deterioration parameter is No. 37. According to the principles of invention No.27 and No.34. The feasible solution is to install sensors and multiple clamping holes on the rotating plate. Each clamping hole is equipped with an arc clamp plate that is sliding and connected internally.

When the paintbrush enters the clamping hole, the sensor senses and operates, automatically clamping the paintbrush according to its size, achieving cleaning of different types of paintbrushes, greatly saving manpower, and improving device automation.

(1) From an environmentally friendly design perspective, if the device does not have an automatic recycling function, it will require frequent manual water or cleaning agents, resulting in a waste of manpower and resources, and is not suitable for outdoor sketching use;

If it has a circulation function, it is necessary to add a centrifugal separation process to separate water and impurities from the used sewage in the device, as well as a micro water pump, so that the discharged liquid can be pumped back into the treatment tank. This will lead to a significant increase in the cost of the device. Extracting the improvement parameters and deterioration parameters from them is the increase in recycling function and device cost, respectively. Substituting them into the conflict matrix, the corresponding invention principles can be obtained as No.25, No.27, and No.34, as shown in Table 6 Environmental Protection Design Improvement.

Table 6 Environmental Protection Design Improvement

Project	Specific Parameters	General Engineering Parameters	Corresponding Invention Principles
Improve parameters	Recycling function	No.38 automaticity	No.25 Self-service principle No.27 Cheap substitutes
Deterioration parameters	Increased device costs	No.37 The difficulty level of monitoring and testing	No.34 Partial exclusion and regeneration principles

As shown in Table 6. The improvement parameter of the device is No.38, and the deterioration parameter is No.37. According to the corresponding available invention principles, No. 27 is a cheap substitute. No.34: Exclusion and regeneration principles. The proposed solution is to use commonly available and inexpensive filters instead of centrifuges to separate wastewater, and then choose low-priced and readily available micro water pumps to pump the water back into the treatment tank for reuse.

(2) From the perspective of safety design, if the device does not have a timing function, it is easy to cause excessive cleaning of the paintbrush or safety hazards; If the device has a timing function, it can avoid the above problems and save power consumption, but it needs to increase the production cost of the device. Extracting improvement parameters and deterioration parameters from them are timing function and device cost increase, respectively, and substituting them into the conflict matrix to search for the corresponding invention principles, as shown in Table 7 Safety Design Improvement.

Table 7 Safety Design Improvement

Project	**Specific Parameters**	**General Engineering Parameters**	**Corresponding Invention Principles**
Improve parameters	Timing function	No.15 Action time of moving objects	No.19 Principle of periodic action

Deterioration parameters	Cost increase	No.37 The difficulty level of monitoring and testing	No.29 Principles of using pneumatic and hydraulic pressure structures No.35 Principle of changing the aggregation state of objects No.39The principle of using inert media

As shown in Table 7. The improvement parameter of the device is No.15, and the deterioration parameter is No.37. According to the corresponding available invention principle, it is No.19. The feasible solution is to set a fixed timing function in the device, with a cleaning process lasting for 15 minutes each time. After cleaning, the power will be automatically cut off, saving power resources. It avoids excessive cleaning without supervision, which can cause harm to the paintbrush and other electrical safety hazards.

6.2.5 Analysis of Material Field Models

According to the analysis of the physical field, there are technical system issues between the clamping hole and the brush. A pre-improved physical field model is established, as shown on the left in Figure 5 Substance-Field model before and after Improvement of Clamping Holes and Brushes.
Solve problems according to standard solutions No.2 and No.9. Namely, No.2 allows the addition of a permanent or temporary internal additional component while the system remains unchanged.
No.9, when useful and harmful effects coexist in the design, field 1 and field 2 do not need to be in direct contact, and field 3 is introduced to eliminate bad effects. The solution is to install an arc clamp plate on the clamping hole. The arc clamp plate has anti-slip lines and a rubber cushion for shock absorption, which not only has a certain toughness and is not easy to break but also can firmly fix the brush and reduce the compression and wear of the brush by the clamping hole. The improved physical field model as shown in the right side of Figure 5.

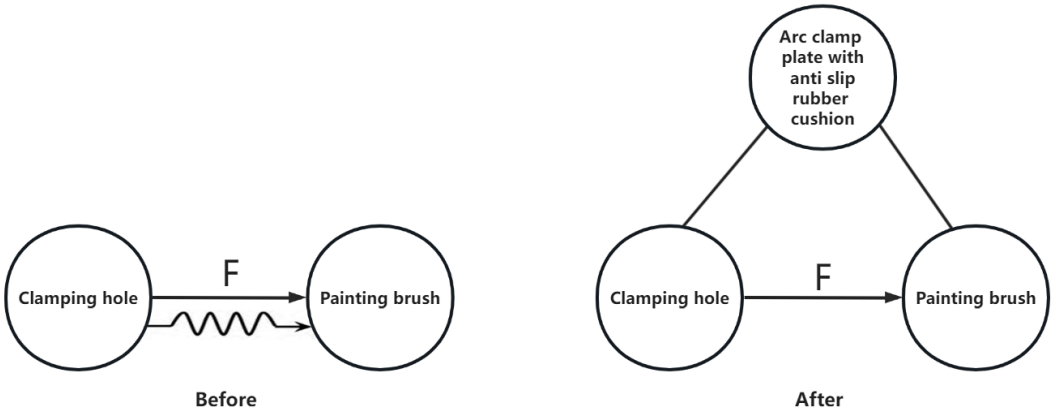


Figure 5 Substance-Field model before and after Improvement of Clamping Holes and Brushes

According to the analysis of the physical field, there is a technical system issue between the collection box and the micro water pump. The left side of Figure 6 Substance-Field Model before and after Improvement of the Collection Box and Micro Water Pumpshows the improved physical field model.
According to standard solution No.3, the problem is solved by adding permanent or temporary external objects without changing the system. A filtering device is installed above the inside of the collection box to filter the sewage when it flows down from the treatment box, separating impurities and allowing the filtered liquid to flow into the collection box. When passing through the micro water pump, it will not cause blockage and can be reused multiple times. On the right of Figure 6 Substance-Field Model before and after Improvement of the Collection Box and Micro Water Pump, is the improved physical field model diagram.

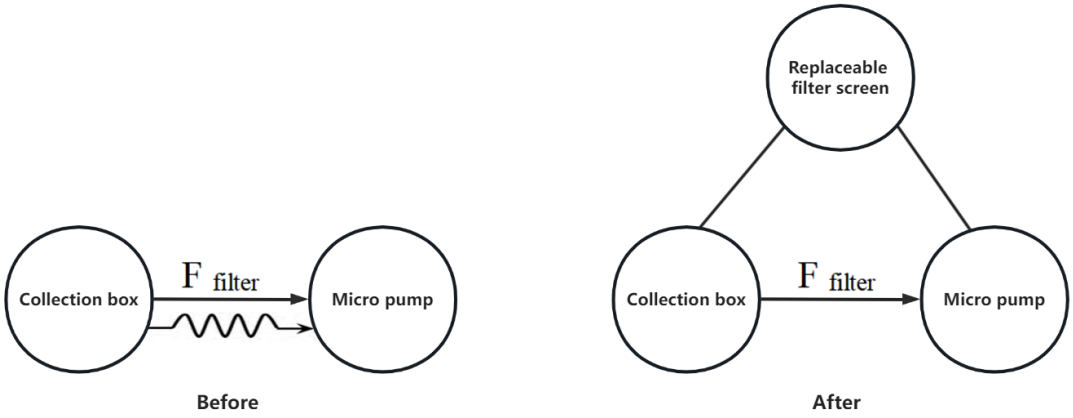


Figure 6 Substance-Field Model before and after Improvement of the Collection Box and Micro Water Pump

7. THE FINAL OPTIMIZED DESIGN SCHEME BASED ON THE COMBINATION OF 5 KANO AND TRIZ

In summary, based on the TRIZ invention principle, a total of eight optimized design schemes have been developed for this brush-cleaning device, as listed in Table 8 Optimization Plan for the Automatic Cleaning Device of the Brush. Based on the actual situation of the automatic cleaning device for paintbrushes and user evaluations in the KANO model, the feasibility of the scheme was evaluated, and the optimal solution was ultimately determined to be 1, 2,3,4, 5, 6, 7, and 8.

Table 8 Optimization Plan for the Automatic Cleaning Device of the Brush

No	program	Innovative principles	Availability assessment
1	Change the clamping hole mode	No.27 Cheap Substitute No.34 The first principle of partial elimination and regeneration	Available
2	The device has a recycling function	No.27 Cheap Substitute No.34 The first principle of partial elimination and regeneration	Available, but requires a slight increase in cost
3	Improve brush cleaning cycle	No.19Principle of periodic action	Available
4	Add a movable seat with rubber burrs inside the fixed seat	Separation principle	Available
5	Change the integrity of the device	Separation principle	Available
6	Changing the power storage function of the device	Separation principle	Available
7	Add arc clamp plates with anti-slip and shock-absorbing effects to the clamping holes	Material Field Model and Standard Solution	Available
8	Add replaceable filters	Material Field Model and Standard Solution	Available

The final solution obtained through schemes 1, 2, 3, 4, 5, 6, 7, and 8 is to change the clamping hole pen clamping mode, the device's recycling function, fix the timing cleaning to add a moving seat, change the overall integrity of the device, change the device's power storage function, add an arc clamp plate with anti-slip and shock-absorbing effect on the clamping hole, and add a replaceable filter screen (Wang, 2022).
There are sensors and multiple clamping holes on the rotating plate, and each clamping hole is equipped with a sliding connected arc clamp plate inside. When the sensor senses the brush entering the clamping hole, the arc clamp plate will automatically advance and fit the pen holder, thereby enabling the entire device to automatically clamp various specifications of brushes.

(2) Add moving seats with rubber burrs inside the fixed seats on both sides of the partition board, allowing it to move back and forth from right to left. Not only can it efficiently clean the stains deep inside the brush, but it can also protect the brush head.
(3) The device is equipped with a fixed timing function. After the device cleaning test, it was found that the effective cleaning process was 15 minutes. After cleaning, it automatically shuts off the power, which can prevent damage to the paintbrush caused by excessive cleaning time, save power resources, and avoid safety hazards.
(4) Add a movable seat with rubber burrs inside the fixed seat to achieve efficient cleaning and protect the paintbrush.
(5) The interior of the processing box is divided into two cavities, one is the processing box, and the other is the collection box. The outer shell of the processing box accommodates the collection box, and the inner wall of the processing box is in contact with the outer wall of the collection box. The processing box is completely in contact with the base of the collection box, forming a closed structure. It not only ensures stability and sealing during cleaning but also has a detachable function for regular maintenance and cleaning.
(6) Changing the plug of the device to a USB interface allows for the connection of the plug indoors and the use of a power bank outdoors, reducing the weight and volume of the device and enhancing its practicality.
(7) Install an arc clamp plate on the clamping hole, which has anti-slip lines and a rubber cushion for shock absorption, making it resilient and not easily broken. It can also firmly fix the brush and reduce the compression and wear of the brush by the clamping hole.
(8) A filtering device is installed above the inside of the collection box to filter the sewage when it flows down from the treatment box, separating impurities and allowing the filtered liquid to flow into the collection box. When passing through a micro water pump, it will not cause blockage, which can not only replace low-cost centrifuge technology but also achieve recycling and reduce environmental pollution.

8. DESIGN MODEL OF AN AUTOMATIC CLEANING DEVICE FOR 6 BRUSHES

Based on the feasible solutions selected above, the optimal design of the brush cleaning device is carried out, and a model diagram of the device is constructed. The front view of the device as shown below Figure 7, and the side view is in Figure 8.

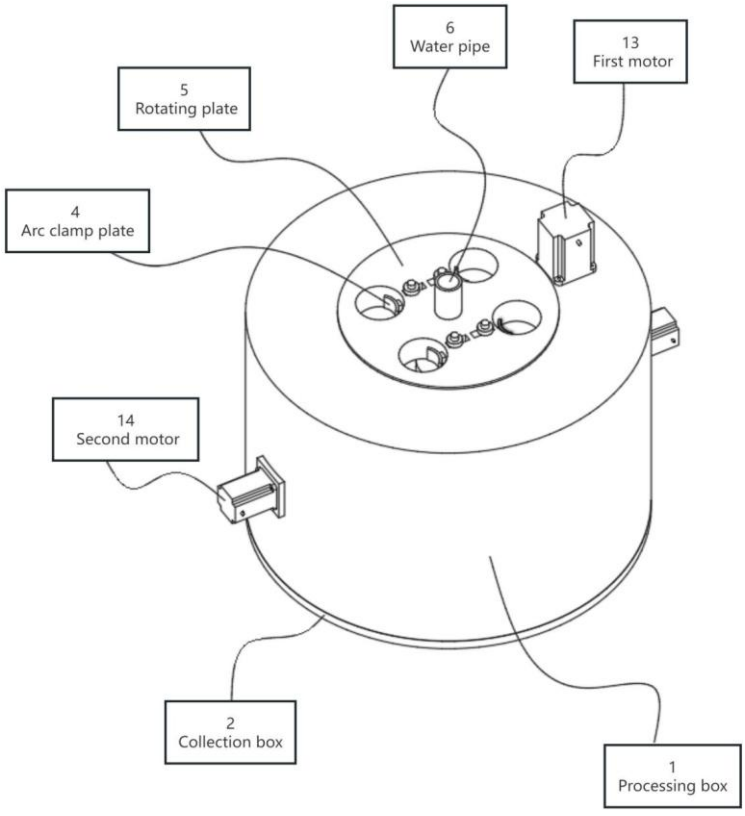


Figure 7 Elevation View of the Device

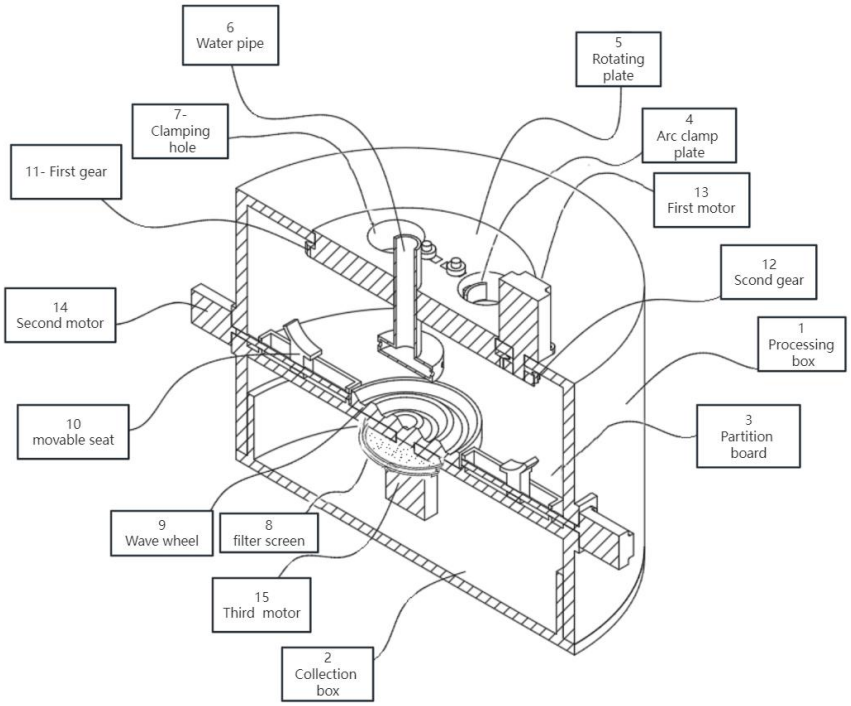


Figure 8 Side View of the Device

9. CONCLUSION

This study focus on optimize the design of an automatic brush cleaning device, with the aim of improving its overall performance and user experience. The research team delved into multiple key aspects of the device, including functionality, safety, environmental friendliness, and portability. To achieve this goal, researchers used the KANO model and TRIZ theory as the main analytical tools. The KANO model helps researchers better understand the hierarchy of user requirements for product functionality, while the TRIZ theory provides a systematic and innovative approach, particularly for the analysis of physical contradictions, technological contradictions, and physical field models.

During the research process, the researchers analyzed in detail the standard solutions of 76 TRIZ theories and proposed six potential optimization solutions based on in-depth insights from the KANO model. After rigorous evaluation and screening, the five most feasible and innovative solutions were ultimately determined. These solutions have been validated in practical applications, with particularly noteworthy being the optimized design of clamping hole mode, cyclic use function, mobile seat, arc clamp plate, and filter screen.

The optimization of the clamping hole mode makes the fixation of the brush more stable and convenient, while the introduction of the recycling function greatly improves the efficiency and environmental performance of the cleaning device. The design of the mobile seat makes the device more flexible and adaptable to different usage environments, while the improvement of the arc clamp plate enhances the structural stability and durability of the device. The optimized design of the filter effectively improves the cleaning effect and ensures clean water quality during the cleaning process.

Through these optimization measures, the automatic brush cleaning device has not only significantly improved in performance, but also made a qualitative leap in user experience. The application of KANO model enables researchers to accurately grasp user needs, while the application of TRIZ theory provides a fast, accurate, and efficient method for solving complex problems. The successful implementation of these optimization schemes not only validates the effectiveness of theoretical tools, but also provides reliable data support and practical guidance for the research of similar products in the future. At present, the brush automatic cleaning device designed in this study has obtained national level new utility patents and appearance design patents, and we hope to further optimize it through continuous technological iteration and user feedback, becoming a leading product in the market that combines efficiency, environmental protection, and convenience. In the future, the team will continue to explore more innovative technologies, fine tune based on user feedback, strive for excellence in details, and

ensure that the device can perform well in various usage scenarios, truly achieving the perfect integration of artistic creation and environmental protection concepts.

10. DATA DECLARATION

The data in this study does not harm the rights and interests of others, and there are no disputes of interest. The data on user reviews of the product was obtained through Python web crawling, and the KANO questionnaire user satisfaction survey was obtained in the form of an online questionnaire. All the tables and figures are drawn by the author, and the research and design are original.

11. AVAILABILITY OF DATA AND MATERIALS

This study promises that the data is authentic and reliable. Parts of the data generated and analyzed during this study are included in this article. The other datasets used and analyzed during the current study are available from the corresponding author on reasonable request.

12. DISCLOSURE OF BENEFITS: There is no conflict of interest in this article.

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