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An Innovative Design for Cleansing, Deodorization, and Pest Control in Drain Covers: Application of the TRIZ Method and Human Factors Engineering

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Abstract: This study explored an innovative design of a drain cover for dirt removal, deodorization, and pest control. The research methods used in this study included an analysis of the literature, the TRIZ method and general design, and application of human factors engineering. Firstly, the contradiction matrix of the TRIZ method was used to find out the corresponding principles of invention for analysis. Based on the reference of the most innovative design, a drainage cover with rapid cleansing, deodorization, insect-repellent properties, and quick return was designed, and universal design was used to make the drainage cover. The innovative design can be more widely used to allow users to interact with the environment and products more harmoniously, and the innovative design of the drainage cover was faster and more hygienic through the human-computer interaction in the project. Additionally, the design was validated through analyses using the IPA and Kano models, confirming that it met the users' requirements and expectations. The prototype's structure was drawn by Autodesk Inventor drawing software (2024). The research results are as follows. We designed a sliding groove and the sliding block on the drainage cover so that the drainage cover could achieve the effect of rapid cleansing by sliding the sliding block. In terms of the odor control and pest prevention, we designed the odor-resistant block and the water filter under the drain cover so that the odor below the drain would not float upwards. And the pests in the drain hole cannot climb out. In terms of the improved operational design, the sliding block could be quickly returned and the use of the pushing aid to not touch the dirt. The successful development of the product validated the effectiveness of this research method for innovative product design and suggests its applicability for the development of other products.

Keywords: drainage cover; anti-dirt and insect-proof; human factors engineering; TRIZ; universal design

1. Introduction

Drainage covers are common necessities in normal life and are often cleaned from obstructions so that the drainage effect of the drainage cover is normal, and there are many reasons that hinder the drainage effect of the drainage cover.

The top five reasons for clogging are grease and fat, hair, foreign objects, toiletries, and trees and leaves. Among them, grease and fat are one of the most common causes

of blocked drains; used cooking grease and fat are also the easiest to prevent. Although it may seem too delicate to cause any major blockages, the build-up of hair down a plug can stop water passing through it altogether and, in turn, can create a large problem for homeowners. Further, tree roots are drawn to the nearest source of water and can cause pipes to crack over time, creating blockages [1].

There are many ways to clean the common drain cover, such as using tweezers or picking up dirt or pouring corrosive agents to achieve a cleaning effect, but it takes a while to clean, and some foreign objects may not be able to be cleaned away. Corrosion needs to be cleaned by hand. However, there is no faster and more hygienic way to clean a drain cover. There are seven ways to remove hair from a drain cover, including bicarbonate of soda and vinegar, tweezers, wire coat hangers, hair removal cream, vacuum cleaners, plungers, and commercial cleaning products. If one is able to lift or unscrew the plughole and wants fast results, tweezers are the ideal solution. This is achieved by opening the plughole and using tweezers to fish for any unwanted hair around the opening of the drain—it is that straightforward. It may seem like the more gruesome approach but is regarded as the simplest and quickest way. If the hair just will not budge, it is time to bring out the drain cleaner. Purposely designed to tackle these situations, there are many products that will quickly dissolve hair and soap scum lurking in your pipes. Purchasing a plughole cover can also be a good investment, as it acts like a sieve, stopping any hair from flushing down the drain in the first place [2].

This study explored the innovative design of a drain cover for the removal of dirt, odor, and insects. The purpose was to improve the traditional drainage cover without cleansing and the absence of deodorant and insect-proof properties. This study used the TRIZ method to improve, through the use of the technical contradiction matrix, and design a drainage cover that could quickly decontaminate and deodorize, and prevent insects, and then used the universal design to improve the interaction with people and the environment, and finally used human factors. The human-machine interaction of the project made the operation of the drain cover faster and more sanitary.

2. Literature Review

2.1. Drainage Cover Products

Using “anti-hair drainage cover” as a key term, data retrieval was conducted through multiple large online shopping platforms’ search systems. The search results primarily fell into two categories of products. The following section describes two selected products related to this topic.

1. A square-shaped water outlet net attached to the lever

This product is designed for drainage ports with square dimensions, such as 10 cm × 10 cm, and features anti-insect, anti-mosquito, and anti-blocking functions. It can be securely locked into the original metal drain hole cover using a cover rod screw, facilitating the removal of hair from the filter screen. The filter mesh has a convex design to intercept hair, and a pull ring design for easy removal of the hair. Additionally, the silicone frame can be trimmed to fit smaller square frames as needed.

2. The two-in-one push-type flexible odor-resistant drain hole cover

This product is suitable for drains with specific dimensions and is constructed from high-quality silicone and stainless steel. It is designed to prevent impurities such as hair from entering the drainage hole, and offers deodorizing, insect-proof, and ultra-convenient closure functions.

2.2. Human Factors Engineering

In the early days of the United States, the human factor project was called human engineering. Now the name is human factors engineering or it is referred to as human factors. Human factors engineering aims to improve the relationship between people and tools, machines, equipment, and the environment through design to achieve the best

cooperation [3,4]. Human factors engineering uses scientific principles, methods, and data extracted from various disciplines to develop systems in which people play an important role. The field of application extends from a single person using simple tools to a complex multi-person social and technological organization [3,4]. Human factors engineering (HFE) is the study of the impact of workplace design and the workplace environment on people and includes those issues that have an impact on the body's structure and functioning [5,6].

The human-machine system is defined as the use of various technological products for the design of human-machine systems. Most of the systems include personnel, machines, and functions to be performed to produce some form of output. For human factors engineering, people are part of the system, so in the design phase, people must be fully integrated into the system [7]. A previous study reported the effort at two large, integrated healthcare systems that used human factors engineering approaches to the information layout design of new patient identification armbands. The different methods used illustrated potential pathways to obtain standardized armbands across healthcare systems that incorporate human factors principles [8].

The primary purpose was to provide a human factors engineering (HFE) checklist for upgrades of human-system interfaces (HSIs) in nuclear power plants (NPPs). The HFE checklist was used to review the HSIs' design submissions prepared by licensees or applicants for a license or design certification of a HSI upgrade. The results showed that the HFE checklist had sufficient validity and reliability for the review of HSI upgrades in NPPs [9,10]. Human factors are complex areas, derived from cognitive psychology and other humanities. The goal is to ensure that the readers understand key principles and have the ability to seek more detailed information or advice to develop a human-machine interface that effectively supports users' interaction and reduces the risk of human error [11]. These collaborative projects also aimed to improve the operators' and the plant's performance, and to avoid the introduction of new human error hazards in both routine and abnormal plant conditions [12].

2.3. Universal Design

The evolution of design began in the 1950s, when people began to notice the problems of people with disabilities in their lives. In Japan, Europe, and the United States, "barrier-free design" removed various obstacles that existed in the environment for people with physical and mental disabilities. In the 1970s, Europe and the United States adopted "accessible design" for the needs of people with limited mobility in the living environment, not for products. Universal design is a design philosophy that aims to create an inclusive, sustainable society where everyone can participate as much as possible [13,14]. Universal design products benefit users with many different capabilities, limitations, and needs. The designer's new challenge is how to design products that are both usable and interesting, no matter who the user is. The goal is to design accessible and equitable environments through universal design [15]. The general design philosophy is to transform into inclusiveness and provide promising and improved solutions for people with different capabilities. However, usually, in practice, it is just a concept [16].

Barrier-free design focuses on improving the function or planning of equipment or space. Some barrier-free design practices that are too specific may lead to discrimination or may not be accepted by the public, while universal design focuses on a wider range of aspects, including the users' physiology as well as psychological and other aspects. In other words, the barrier-free design takes into account the operating conditions of the disabled when using the device or space, while the universal design takes into account the user's use, but also the psychological feelings regarding the use [14]. There are many products in life that are used in universal design, such as double-opening refrigerators that make it easy for left-handers to open a refrigerator door.

This growing interest is also visible in the European Union's transport policy, aiming at securing the rights of passengers with reduced mobility. However, big differences in local standards of designing public spaces and transport infrastructure are visible.

Furthermore, particular cities choose different strategies to improve the accessibility of public transport [17]. The seven principles of universal design were proposed in 1990 by American designer Ronald L. Mace and others, and these seven principles are currently the most representative and most commonly proposed, can be used to assess whether the existing design meets the universal design, and gives the designer of a design the specific considerations early [18,19].

2.4. TRIZ

TRIZ is a knowledge-based system invention and problem-solving method [20–22]. It provides a systematic approach to finding technical solutions and improving the innovation of technical systems [23–26]. TRIZ is the abbreviation for the Russian word “Teoriya Resheniya Izobreatatelskikh Zadatch”, translated into the theory of innovative problem solving. Created by Mr. G. Altshuller in 1940, it is a process that provides systematic theory to guide innovation [25,26]. After analyzing more than 400,000 patents, we compiled a series of innovative methods, among which, the most widely known is the TRIZ contradiction matrix, which uses the contradictions encountered in the design of products in the way the parameter values are interlaced to find the innovative rules of the solution [27].

The TRIZ method can also be successfully used for understanding and solving complicated problems of management. Until new solutions in mounting, designed for ultrasonic welding automated workplaces, enter production, they are verified by computer simulations to test their mechanical features and, if necessary, another optimization of the designs will be performed [28]. For practical use of TRIZ in technical areas, it is necessary to have a number of specialized versions of TRIZ differing in the nomenclature and content of information assets. The same target can be set regarding the construction industry [29]. Staff members with high engagement and highly developed creativity and innovation ability help companies establish an advantageous market position by creating innovative products and services. This process can be positively influenced by applying the methods and tools of the TRIZ innovation methodology [30]. Research has investigated the potential correlations between solution paths and resolved problems, serving as a basis for developing guidelines or standards to assist designers in selecting appropriate inventive principles. The findings indicate that the choice of inventive principles follows a logical mechanism rather than a random occurrence, with the types of contradictions resolved and the disciplinary fields to which the problems belong playing significant roles [31]. TRIZ classifies different innovation problems and provides the corresponding solutions for various kinds of problems. The tool includes 39 engineering parameters to develop contradictory matrices and 40 invention rules, and even some companies based on TRIZ and patent databases. To create a computer-aided innovation system, the automation of invention and innovation has a glimmer of hope [32]. TRIZ is a product and process innovation method that uses various tools that propose paths to possible innovations and solutions. As such, TRIZ promises it could be use in research into the compatibility of TRIZ, and maintenance guidelines were explored using a three-stage research plan [33]. In Europe and the United States, a switch to a knowledge-intensive production industry is actively pursued. Especially in these knowledge-intensive branches of industry, proper protection of IP is of utmost importance to obtain and maintain a profit-making advantage over competitors. These companies define patenting strategies that go beyond the patent of just single products or processes. The decisions on these patenting strategies are made by specific IP departments after the development process. The main question to be answered is if a company’s patent strategy is better served if the product’s designer can take this strategy into account during the concept development stage [34].

2.5. IPA-Kano Model

The Importance–Performance Analysis (IPA) method primarily uses the mean or median values of importance and satisfaction as reference lines, dividing the importance and satisfaction of a product into four quadrants on a Cartesian plane: keep up the good

work, concentrate here, low priority, and possible overkill. This approach facilitates discussions on improvements in products' quality and maintenance plans within limited resources, enhancing products' competitiveness [35]. The Kano two-dimensional quality model categorizes a product's quality attributes into five dimensions: attractive quality, one-dimensional quality, must-be quality, indifferent quality, and reverse quality. The final attribute characteristics are determined by the cumulative frequency of respondents' answers to various quality attributes [36]. In recent years, an increasing number of studies have combined IPA with the Kano model. The IPA-Kano model can avoid the Kano two-dimensional classification overlooking the importance of quality and performance, while also addressing the limitation of IPA's consideration of only one-dimensional quality. This combined model allows for a more accurate assessment of the users' perceptions of a product's quality attributes and enables designers to formulate more effective improvement strategies [37,38].

3. Research Design

The research focused on an innovative design for rapid cleansing, pest control, and odor-resistant drainage covers, based on the abovementioned objectives and related literature. To achieve these objectives, the study used drainage cover analysis, patent analysis, the TRIZ method, general design principles, and human factors engineering. The TRIZ method used 39 engineering parameters (Table 1) [39] and 40 invention principles (Table 2) [40] to innovate the drain cover's design. Engineering parameters that needed improvement or had potential drawbacks were identified and mapped onto the contradiction matrix. The intersection of these parameters revealed relevant inventive principles, which were prioritized to resolve the design's contradictions. This method generated a matrix guiding the systematic exploration of creative solutions, balancing conflicting requirements, and overcoming the design's trade-offs. Additionally, the research incorporated general design principles to ensure the practical applicability and manufacturability of the solutions. Human factors engineering was integrated into the design process, focusing on ergonomics, safety, and ease of maintenance. This comprehensive approach combined analytical rigor with creative problem-solving, aiming to produce innovative drain cover designs optimized for user interaction and real-world implementation.

Table 1. Summary of the 39 engineering parameters.

1. Weight of the moving object	11. Stress or pressure	21. Power	31. Object-generated harmful factors
2. Weight of the stationary object	12. Shape	22. Loss of energy	32. Ease of manufacture
3. Length of the moving object	13. Stability of the object's composition	23. Loss of substance	33. Ease of operation
4. Length of the stationary object	14. Strength	24. Loss of information	34. Ease of repair
5. Area of the moving object	15. Duration of action by the moving object	25. Loss of time	35. Adaptability or versatility
6. Area of the stationary object	16. Duration of action by the stationary object	26. Quantity of the substance/matter	36. Device complexity
7. Volume of the moving object	17. Temperature	27. Reliability	37. Difficulty of detecting and measuring
8. Volume of the stationary object	18. Intensity of illumination	28. Measurement accuracy	38. Extent of automation
9. Speed	19. Use of energy by the moving object	29. Manufacturing precision	39. Productivity
10. Force	20. Use of energy by the stationary object	30. External harm affecting the object	

Table 2. Summary of the 40 invention principles.

1. Segmentation	11. Early cushioning	21. Skipping	31. Porous material
2. Tanking out	12. Equipotentiality	22. Convert harm into benefit	32. Changing the color
3. Local quality	13. Working in reverse	23. Feedback	33. Homogeneity
4. Asymmetry	14. Spheroidality–curvature	24. Intermediary	34. Discarding and recovery
5. Merging	15. Dynamicity	25. Self-service	35. Transformation of properties
6. Universality	16. Partial or excessive actions	26. Copying	36. Phase transition
7. Nested doll	17. Transition into a new dimension	27. Cheap, short-lived objects	37. Thermal expansion
8. Anti-weight	18. Mechanical vibration	28. Replacement of mechanical systems	38. Accelerated oxidation
9. Prior anti-action	19. Periodic action	29. Pneumatics and hydraulics	39. Inert environment
10. Preliminary action	20. Continuity of useful action	30. Flexible shells or thin films	40. Composite materials

3.1. The TRIZ Method to Introduce the Innovative Design of the Drainage Cover for Rapid Cleansing

In the conventional traditional drainage cover, only dense small holes block the foreign matter from invading the drainage port to avoid the drainage hole being blocked, but the drainage cover can be entangled by foreign matter, hair, skin particles, etc., so that the drainage effect of the drainage cover is reduced, causing a blockage. When the drain cover is clogged, the hand or a cleaning solvent can be used to remove the debris or corrode the foreign matter and hair and then clean it. In the process of cleaning, it is necessary to contact the foreign matter with the hand and the drain cover and to wait for the cleaning time of the cleaning agent. In order to solve these problems, an innovative design of a rapid-cleansing drainage cover is based on the 39 engineering parameters of the TRIZ technical contradiction matrix, and the parameters to be improved were No. 3 (length of the moving object), No. 7 (volume of the moving object), and No. 36 (complexity of the device), while avoiding deterioration in parameters No. 27 (reliability), No. 33 (convenience of use), and No. 35 (adaptability) using the engineering parameters above to produce a contradiction matrix corresponding to the inventive principles, as shown in Table 3.

Table 3. Technical contradiction matrix for the rapid-cleansing drainage cover.

“Avoid Deterioration” Parameters “Want to Improve” Parameters	27. Reliability	33. Convenience of Use	35. Adaptability
3. Length of moving object	10, 14 29, 40	15, 29 35, 04	14, 15 01, 16
7. Volume of moving object	14, 01 40, 11	15, 13 30, 13	15, 29
36. Complexity of device	13, 35 01	29, 09 26, 24	29, 15 28, 37

3.2. Innovative Design and Universal Design to Introduce a Quick-Cleansing Drainage Cover

In the innovative design of a rapid-cleansing drain cover, in order to match the principle of sliding the drain cover and the push block, the drain hole of the drain cover is drained downwardly, and the drain cover and the sliding track are visible from above. Hair and foreign matter cannot flow into the gap, but instead are trapped on the upper track of the drain cover. This design enhances the cleansing effect of the drain cover. The hair and foreign matter collected on the rail can then be quickly removed by pushing the block, ensuring efficient maintenance of the drain cover. Based on the above characteristics, we

applied the principles of fair use, simple and intuitive use of universal design, and saving effort to improve the innovative design of the drainage cover for rapid cleansing.

1. Equitable use: This design will not cause any harm to any user, and the weight of the drain cover will be the maximum weight, which makes it easy for operators of all sizes to operate.
2. Simple and intuitive: This design is easy to understand regardless of the user's experience, knowledge, language ability, or concentration. In the drainage cover's design, the anti-sludging track of the rail is used to make the drainage cover operate in a single direction, and the drainage cover can be easily operated in an intuitive manner.
3. Low physical effort: this design can be used effectively, comfortably, and effortlessly. The loose fit of the sliding rail of the drain cover and the push block enables the push block to push the hair and foreign matter without difficulty.

3.3. The TRIZ Method to Introduce the Innovative Design of a Deodorizing and Insect-Proof Drainage Cover

In a conventional traditional drainage cover, the function of preventing hair and foreign matter from invading the drainage hole does not prevent the smell of the underground pipe of the drainage hole from floating upward, nor can it prevent the pests in the underground pipe of the drainage hole from climbing out or crawling into the drainage from the drainage cover hole. As the method of cleaning the odor discharge, a cleaning agent is poured into the drainage hole to corrode the source of the odor and then the drainage hole is rinsed with clean water. However, the source of the odor is often in the underground pipeline, so sometimes it is impossible to undertake the cleaning of the underground pipeline. If cleaning is carried out, it takes much time and labor costs to clean the latter. In order to solve the problems above, the innovative design of the rapid-cleansing drainage cover was based on the 39 engineering parameters of the TRIZ technical contradiction matrix, and the parameters to be improved were No. 1 (weight of the moving object), No. 16 (durability of the non-moving object), and No. 30 (harmful factors acting on the object), avoiding deterioration in parameters No. 27 (reliability), No. 35 (adaptability), and No. 38 (level of automation) using the abovementioned engineering parameters to create contradictions, corresponding to the inventive principles, as shown in Table 4.

Table 4. Technical contradiction matrix for the drainage cover's deodorant and pest control properties.

"Avoid Deterioration" Parameters "Want to Improve" Parameters	27. Reliability	35. Adaptability	38. Level of Automation
1. Weight of the moving object	01, 03 11, 27	29, 05 15, 08	26, 35 18, 19
16. Durability of the non-moving object	34, 27 02, 40	02	01
30. Harmful factors acting on the object	27, 24 02, 40	35, 11 22, 31	33, 03 34

3.4. Universal Design to Introduce the Innovative Design of a Drainage Cover with Odor Control

In the innovative design of the drain cover to control odor and insects, there is a return spring. When there is water entering the drain, the deodorant and insect-proof block is lowered by the weight of the water, so there will be a gap between the odor-resistant baffle and the water filter, so that the water can quickly flow into the water outlet of the falling head. When the drain cover is not in use, it is returned by the elastic force of the spring, quickly pressing the odor-resistant and insect-proof blocking piece upwards to press against the filter plate, and keep the space between the drain cover's filter plate and the odor-resistant block closed to ensure that odor will not float out of the drain cover. In addition, cockroaches and other pests are also completely blocked below the odor-resistant slats to keep the environment clean and hygienic. In light of the characteristics above, we

believe that users can understand the message through a variety of sensory organs and minimize the burden on the body during use. It can be used as a basis for preventing odor and insects.

1. Perceptible information: the necessary information can be effectively communicated to the user regardless of the surrounding conditions or the user's sensory ability. The deodorant and insect-proof design of the drainage cover can automatically achieve the effect of deodorizing and pest-proofing, so there is no need to manually operate it, and the principle of actuation is also very simple and suitable for various users.

2. Low physical effort: The reasonable operation makes the user's movements accurate and reduces repetition, and uses them effectively, comfortably, and effortlessly.

3.5. The TRIZ Method to Introduce the Innovative Quick Return and Operation of the Drainage Cover

Based on the aforementioned innovative design for the quick cleansing of the drainage cover, the current method of using a push block for fast cleansing has shown inefficiencies. Additionally, the manual operation of the push block resulted in the hand coming into contact with dirt and foreign objects, highlighting a lack of convenience and hygiene in the design of the rapid cleansing method. In this study, 39 engineering parameters were used to solve the problems above, and the analysis was summarized as No. 14 (strength), No. 15 (durability of the moving object), and No. 16 (durability of the non-moving object). The parameters for avoiding deterioration were No. 30 (harmful factors acting on the object), No. 33 (convenience of use), and No. 35 (adaptability). The parameters obtained from the analysis were drawn into a technical contradiction matrix, corresponding to the inventive principles, as shown in Table 5.

Table 5. Technical contradiction matrix for the rapid return and operation of the drainage cover.

"Avoid Deterioration" Parameters "Want to Improve" Parameters	27. Reliability	33. Convenience of Use	35. Adaptability
14. Strength	18, 35 29, 40	32, 40 25, 02	15, 03 32
15. Durability of the moving object	22, 01 40, 33	12, 27	01, 35 13
16. Durability of the non-moving object	17, 01 40, 33	01	02

3.6. Universal Design and Innovative Design to Introduce Rapid Return

As an innovative design for quick return and operation, the push block can quickly return. The dovetail track of the push block has the effect of a foolproof design, as it can be loaded in only a single direction, allowing the track to quickly return, and this operation added a new accessory. It can be used to quickly remove dirt when used in conjunction with push blocks. On the other hand, it is safe and hygienic in use because the user does not touch the dirt. On the basis of the characteristics above, we believe that the method of use is simple and easy to understand, allows for errors and fairness, and can be used as a basis for quick installation and disassembly of the foolproof device.

1. Simple and intuitive: It is easy to understand how to use it, regardless of the user's experience, knowledge, language ability, or concentration. It can be used without special knowledge or technical training. The drainage cover is designed with a single direction of fastening and the use of a launching aid. It is a design that a user can know how to operate through general intuition. It is simple and clear to use.

2. Tolerance of error: It is necessary to be able to accept the users' operational errors and minimize the adverse effects of danger and accidental or inadvertent actions. Designed with some intuitive hints to avoid the chance of errors, a new recessed hole was added

to the push block and the drain cover, prompting the user to position the hole so that the launching aid can be quickly positioned.

3. Equitable use: This covers a wide range of personal preferences and abilities. The design should be in line with the general public's preferences, emphasizing that the design should be able to meet the needs of a wide range of users and provide users with the freedom to choose how to use them. The quick return and operation of the drain cover allows a variety of users to use it, demonstrating the fairness of a universal design.

3.7. An Innovative Design for Rapid Return and Operation via Human Factors Engineering

This study adopted the human-machine system of human factors engineering. The human-machine system refers to an overall system composed of two subsystems of an interacting and interdependent human and machine in order to achieve a certain intended purpose. We studied the users' interaction with the quick-cleansing, deodorant, and insect-proof drainage cover, and found that the auxiliary aid could not touch the dirt and push it out, but debris remained on the edge of the drainage cover, although it was not visible to the naked eye, but this accumulated for a long time. The drain cover should also be lifted and pushed out so that the hand touches the dirt, so the rear edge of the drain cover was thinned so that the drain cover could be lifted at a single point, and the auxiliary device could be used together with the launching aid. The launching aid could lift the drain cover and push out the dirt. In addition, the users' interaction with the ejector is designed to include a fitting aid that conforms to the human factors engineering. The original launching aid added flexibility, so that it was more labor-saving when re-launching. The accessory was released inadvertently, causing the hand to touch the dirt. This design solves the problem of dust accumulating in the small cover, and did not touch the dirt, making the quick-cleansing, deodorizing, and insect-proof drainage cover more convenient and hygienic.

3.8. Questionnaire Design

This study used the SERVQUAL model to evaluate the prospective value of innovative drain cover designs. The SERVQUAL model served as the theoretical framework, assessing five key dimensions: tangibles, reliability, responsiveness, assurance, and empathy [41]. A structured questionnaire was developed based on the SERVQUAL model, tailored specifically for drain cover users. The questionnaire underwent content validation through expert review. Five experts, representing academia, manufacturing, and retail, participated in semi-structured interviews to refine the questionnaire items, ensuring relevance and comprehensiveness. The study used an integrated IPA-Kano model to analyze the data and provide a comprehensive assessment of innovative drain cover designs. This combined approach leverages the strengths of both frameworks to offer deeper insights into the users' expectations and the product's performance.

4. Product Design

This research design used TRIZ innovation to design the drainage cover to achieve rapid descaling, deodorization, and insect prevention functions, and then used universal design to analyze how to make the function more in line with the principles of universal design. Finally, the human-machine system of human factors engineering was used to improve the design and operate it quickly. Inventor drawing software was used to design and draw the drainage product. The overall drawing and exploded assembly diagram are shown in Figures 1 and 2.

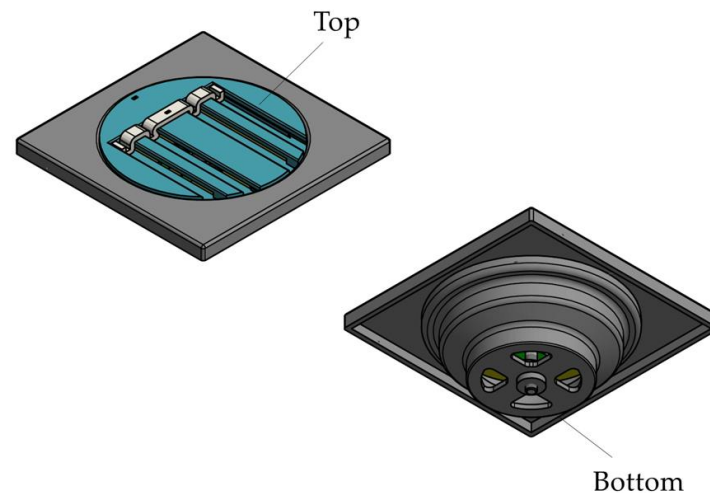


Figure 1. Diagram of the drain cover.

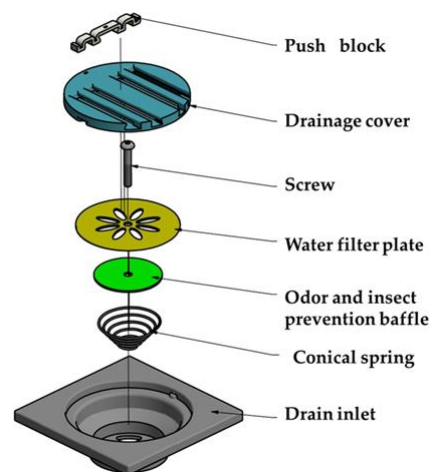


Figure 2. Exploded assembly diagram of the drain cover.

4.1. Product Design for the Rapid-Cleansing Drainage Cover

In the conventional traditional drainage cover, only dense small holes block the foreign matter from invading the drainage hole to avoid the drainage hole being blocked, so that the drainage effect of the drainage cover is reduced, causing a blockage. When the drain cover is clogged, it is necessary to remove or corrode foreign matter and hair by hand or using a cleaning solvent, and then clean it. In the process of cleaning, it is very time-consuming to contact the foreign matter on the drain cover with the hand and wait for the cleaning time of the cleaning agent. To address the aforementioned issues, this study applied the TRIZ method to the design of a product for rapid cleansing of the drain cover. By utilizing the inventive principles derived from the contradiction matrix in Table 1, the study focused on No. 1 (segmentation), No. 14 (spheroidality–curvature), No. 15 (dynamics), and No. 35 (transformation of properties) as the basis for the design of a product for rapid cleansing of the drain cover, and then used universal design to improve it. In this study, a drainage cover with a rapid cleansing function was designed. Using the principles of No. 1 (segmentation) and No. 15 (dynamics), the drainage cover and the dovetail rail of the push block were segmented to allow the push block to slide on the drainage cover, achieving the effect of pushing out the dirt, as shown in Figures 3 and 4. Utilizing No. 14 (spheroidality–curvature) and No. 35 (transformation of properties), the drainage cover and the falling head can be quickly assembled with the curved concave and convex block, and a curved shape was designed at the edge of the ejector to increase the pushing distance. Finally, the thickness of the push block was designed not to exceed the plane of the floor so that it is not kicked by

the foot. This study used a schematic diagram of the quick cleansing function of the drain cover, as shown in Figures 5 and 6.

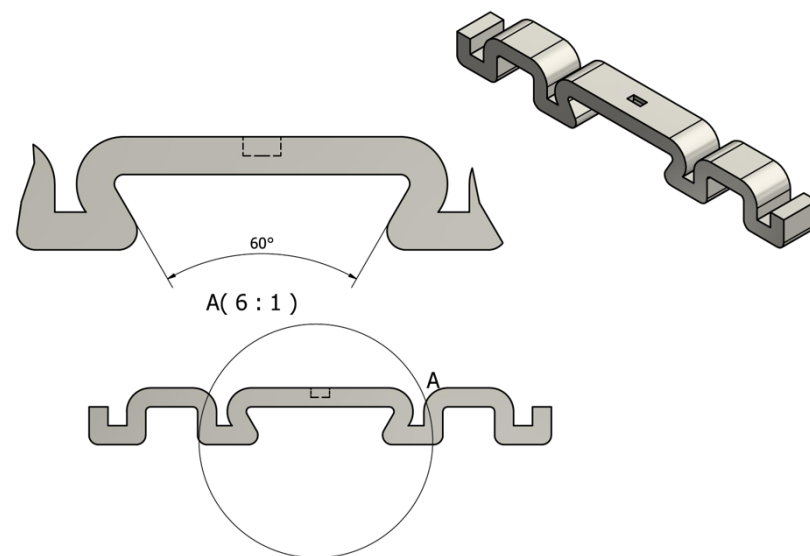


Figure 3. Diagram of the push block.

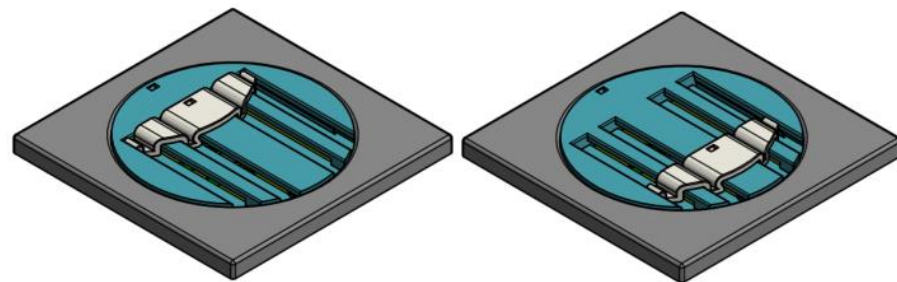


Figure 4. Diagram of the pushing mechanism.

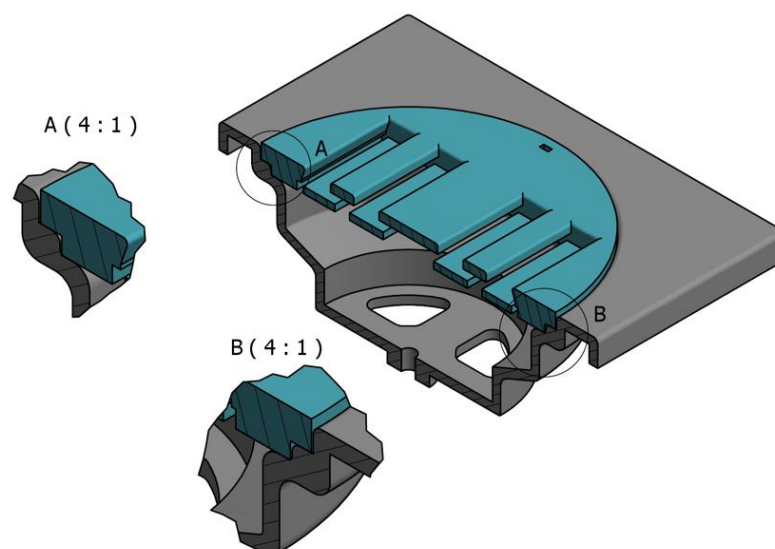


Figure 5. Diagram of the drain cover and drain hole assembly.

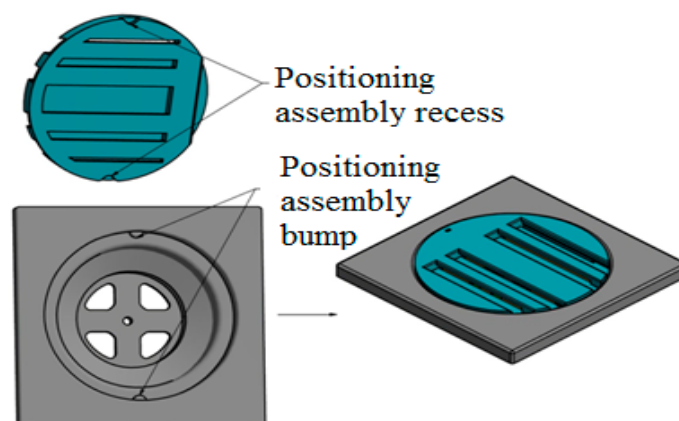


Figure 6. Diagram of the structure of the drain cover and drain hole assembly.

4.2. Product Design of the Deodorant and Insect-Proof Drainage Cover

In the conventional traditional drainage cover, only the function of preventing hair and foreign matter from invading the drainage hole is present, and odor emissions are prevented from floating upward, and the pests in the drainage hole cannot be prevented from crawling out or crawling into the drainage hole. It takes much time and labor costs to make the latter clean. Therefore, in order to solve these problems, this study focused on the design of TRIZ-developed drainage covers with deodorant and insect-repellent properties. By utilizing the inventive principles derived from the contradiction matrix in Table 2, this study found that No. 1 (segmentation), No. 11 (early cushioning), No. 34 (discarding and recovering), No. 35 (transformation of properties), and No. 40 (composite material) could be used as a design basis for the product (the deodorant and insect-proof drainage cover), and then the general design was used for improvement.

In line with No.1 (segmentation), the separation device was divided into a piece of odor-resistant sheet by the separation principle to prevent the odor from coming out. For No. 11 (early cushioning), the odor-resistant and insect-resistant design of the drain cover is deodorized and pest-proof when there is no inflow of water. For No. 34 (discarding and recovering), using the principle of throwing and recycling, a return spring was placed under the odor-resistant slab. When water is not flowing through the drain cover, it can return to the deodorant and insect-proof state. For No. 35 (transformation of properties), the principle of changing the parameters was used to change the spring force coefficient of the return spring so that the weight of the water can push the odor-resistant sheet open.

This design of the deodorant and insect-repellent drainage cover product used the design of the water filter and the odor-resistant barrier to block the odor and pest invasions. The deodorant and insect-proof drainage cover was designed to fix the water filter and the device under the odor-resistant slab. The return spring causes the odor-resistant flap to be attached to the water filter to achieve the effect of blocking the odor and pests. When a large amount of water flows in, the odor-resistant flap and the water filter are separated by the weight of the water to allow the water to flow out of the drain hole. The design of the deodorant and insect-proof product in this study is shown in Figure 7.

4.3. Design of the Drain Cover's Quick Return and Operation Device

Because the quick cleansing function of the drain cover cannot be quickly returned, and the hand touches the dirt during operation, the function of quick cleansing lacks considerations of convenience and hygiene; therefore, the return of the block and drainage for the drainage cover were considered. The operation of the cover was analyzed. Therefore, in order to solve the problems above, this study introduced the product design of the deodorant and insect-proof drainage cover according to the TRIZ method. By utilizing the inventive principles derived from the contradiction matrix in Table 3, this study found that No. 1 (segmentation), No. 33 (homogeneity), No. 35 (transformation of properties),

and No. 40 (composite material) could be used as a design basis for the rapid return of the drainage cover and the design of the operating device. The innovative drain cover design incorporated principles from general design and human factors engineering to enhance functionality, hygiene, and the users' experience. A key feature is the introduction of an auxiliary tool, a specially designed implement that facilitates the handling of the drain cover without direct contact with potentially contaminated surfaces, aiding in lifting, positioning, and removing the cover, as shown in Figure 8. This design utilizes a dovetail track system and a push block mechanism, allowing for quick and secure attachment of the cover, enabling rapid return and efficient operation of the drainage system. The material properties of these components have been optimized for durability and ease of use. The principles of human factors engineering were applied to create an ergonomic human-machine interface, with the auxiliary tool designed for the users' comfort and safety, incorporating features such as finger baffles to prevent slipping during operation. This approach not only enhances ease of use but also significantly reduces the risk of the user contacting unsanitary surfaces. The combination of these design elements resulted in a drainage cover system that is efficient in terms of rapid cleansing, odor control, and insect prevention, while also being superior in terms of the users' safety and hygiene. Figures 9 and 10 illustrate the complete assembly and operation of this innovative design.

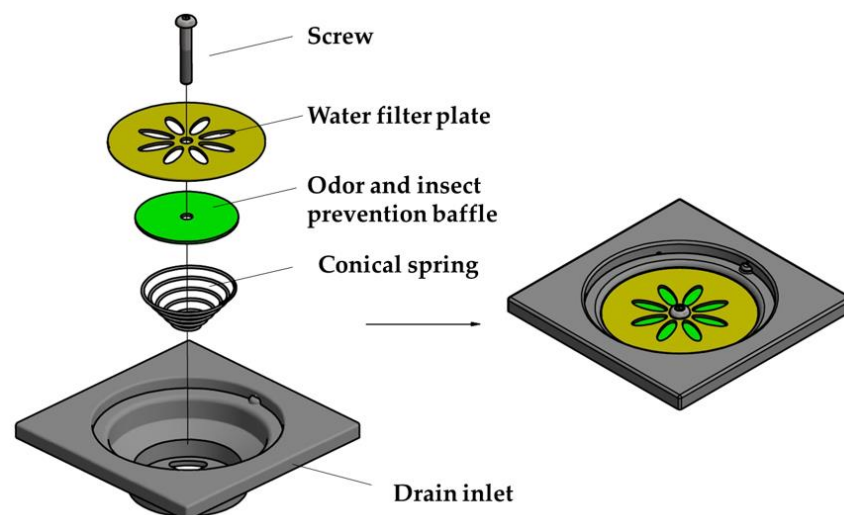


Figure 7. Diagram of the deodorant and insect-proof product design.

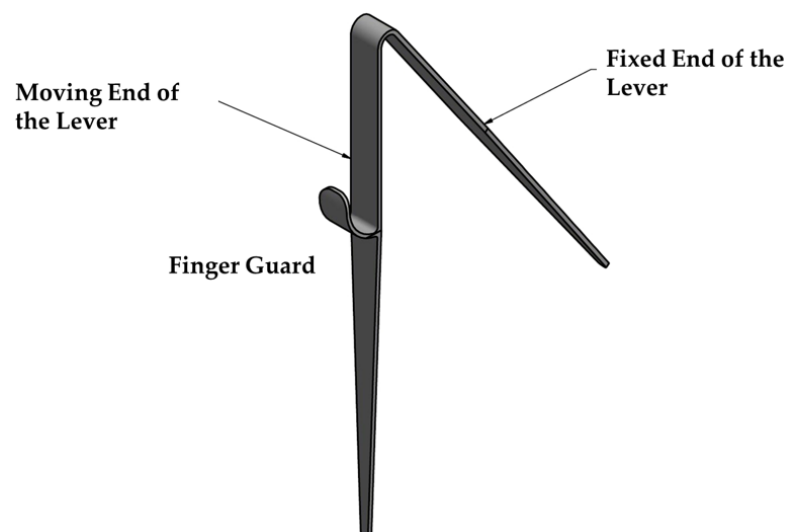
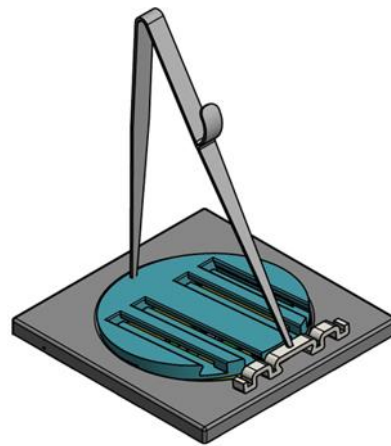
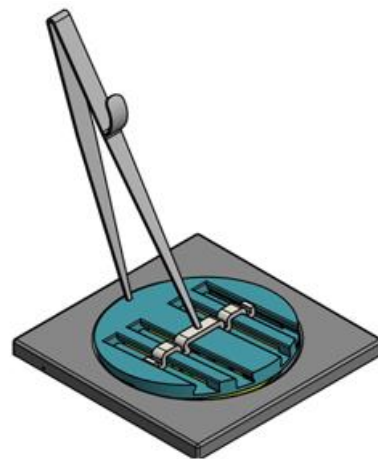


Figure 8. Schematic diagram of the drain cover's operating lever.



1. Preparation

Figure 9. Schematic diagram of operating the drain cover-Preparation.



2. Operation

Figure 10. Schematic diagram of operating the drain cover-Operation.

4.4. Combined Analysis of IPA and the Kano Model

This study conducted a survey to analyze users' perceptions of the importance of and satisfaction with the design of drainage covers. The study sample consisted of 184 participants, with 100 males and 84 females. The characteristics of the respondents, including age, education, occupation, and annual income, are presented in Table 6. The evaluation was performed using the Kano model, which includes the five dimensions of attractive quality (A), one-dimensional quality (O), must-be quality (M), indifferent quality (I), and reverse quality (R), as shown in Table 7. A scatter plot was also created, as illustrated in Figure 11. The results of this study indicated that the overall average importance rating was 4.212, and the overall average satisfaction rating was 4.017. The service quality items that fell into the fourth quadrant, which should be prioritized for improvement, were "basic drainage function" and "easy installation", both of which belong to the must-be quality category. This validated that the innovative design of the drainage cover met the users' needs.

Table 6. Participants' characteristics.

Variables	Numbers	Percentage (%)
Gender		
Male	100	54.3%
Female	84	45.7%
Age		
20–29	37	20.11%
30–39	13	7.07%
40–49	71	35.59%
≥50	63	34.24%
Occupation		
Administrative	32	17.68%
Managerial	7	3.87%
Skilled worker	15	8.29%
Service worker	61	33.70%
Education	41	22.65%
Student	8	4.42%
Homemaker/retired	17	9.39%
Education level		
Junior high school	1	0.54%
Senior high school	3	1.63%
University	154	83.70%
Graduate school	26	14.13%
Annual income		
<500,000 (TWD)	13	7.07%
500,000–700,000 (TWD)	43	23.37%
700,000–800,000 (TWD)	57	30.98%
80,000–100,000 (TWD)	38	20.65%
>1,000,000 (TWD)	33	17.93%

Table 7. Cross-tabulations of IPA and the Kano model.

Quadrant	Service Quality Items	Kano	Importance
I	1. Automatic quick cleaning	A	4.215
	2. Odor prevention	A	4.216
	7. Made with durable materials	O	4.213
	8. Maintains functionality	O	4.214
	10. Overflow prevention	M	4.216
	11. Compliance with safety standards	M	4.219
	16. Weight affects users' experience	I	4.213
II	3. Pest prevention	A	4.209
	4. Easy-to-operate drain cover	A	4.200
	5. Smooth sliding design	O	4.211
	6. Quick opening and closing	O	4.207
III	13. Color affects users' experience	I	4.208
	14. Brand influences choice	I	4.209
	15. Appearance of the design impacts satisfaction	I	4.210
IV	9. Basic drainage functionality	M	4.218
	12. Easy installation	M	4.217



Figure 11. Importance–performance analysis scatter plot.

5. Conclusions

The innovative design of a fast-cleansing, deodorant, and insect-proof drainage cover, developed using the TRIZ method and refined through general design principles, provides significant advancements in usability and effectiveness. This design was rigorously analyzed using the technical contradiction matrix, balancing improved parameters while avoiding deteriorating ones. By integrating human factors engineering, the design process has been enhanced to focus on usability. Validation through the IPA and Kano models confirmed that the design met the users' requirements and expectations.

The key innovative outcomes of this study include a rapid cleansing mechanism with a sliding cover rail and push block system for quick removal of dirt and debris, an odor control and pest prevention system using a water filter and an odor-resistant flap maintained by a return spring, and an improved operational design with enhanced material properties, an ergonomic launching aid, and added safety features such as finger baffles. These features collectively enhance the usability and functionality of the drainage cover.

This study not only showcases an innovative design model that integrates theoretical and practical elements but also demonstrates its effectiveness in meeting users' needs and achieving market innovation. Compared with other state-of-the-art methods, this approach uniquely combines TRIZ methodology with human factors engineering, resulting in a user-centric design that offers significant improvements in usability and functionality.

Future research should explore the application of this innovative design model to other product categories, expanding its impact and potential. Additionally, further studies could investigate the long-term durability of and users' satisfaction with the drainage cover in diverse environmental conditions, ensuring its robustness and reliability. By continuously refining and adapting the design principles outlined in this study, ongoing innovations in product development across various industries can be fostered.

6. Patents

The research results were awarded a utility model patent by the Intellectual Property Office, Ministry of Economic Affairs, Republic of China. (Patent No. M569350).

Author Contributions: Conceptualization, K.-C.Y., Y.-N.C., K.-Y.L., L.-Y.C., J.-R.X., W.-L.H. and W.-S.H.; methodology, K.-C.Y., Y.-N.C., K.-Y.L., L.-Y.C., J.-R.X., W.-L.H. and W.-S.H.; software, K.-C.Y., Y.-N.C., K.-Y.L., L.-Y.C., J.-R.X., W.-L.H. and W.-S.H.; validation, K.-C.Y., Y.-N.C., K.-Y.L., L.-Y.C.,

J.-R.X., W.-L.H. and W.-S.H.; formal analysis, K.-C.Y., Y.-N.C., K.-Y.L., L.-Y.C., J.-R.X., W.-L.H. and W.-S.H.; investigation, K.-C.Y., Y.-N.C., K.-Y.L., L.-Y.C., J.-R.X., W.-L.H. and W.-S.H.; resources, K.-C.Y., Y.-N.C., K.-Y.L., L.-Y.C., J.-R.X., W.-L.H. and W.-S.H.; data curation, K.-C.Y., Y.-N.C., K.-Y.L., L.-Y.C., J.-R.X., W.-L.H. and W.-S.H.; writing—original draft preparation, K.-C.Y., Y.-N.C., K.-Y.L., L.-Y.C., J.-R.X., W.-L.H. and W.-S.H.; writing—review and editing, K.-C.Y., Y.-N.C., K.-Y.L., L.-Y.C., J.-R.X., W.-L.H. and W.-S.H.; visualization, K.-C.Y., Y.-N.C., K.-Y.L., L.-Y.C., J.-R.X., W.-L.H. and W.-S.H.; supervision, K.-C.Y., Y.-N.C., K.-Y.L., L.-Y.C., J.-R.X., W.-L.H. and W.-S.H.; project administration, K.-C.Y., Y.-N.C., K.-Y.L., L.-Y.C., J.-R.X., W.-L.H. and W.-S.H.; funding acquisition, K.-C.Y., Y.-N.C., K.-Y.L., L.-Y.C., J.-R.X., W.-L.H. and W.-S.H. All authors have read and agreed to the published version of the manuscript.

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