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Design and Improvement of Mobility Aid Walker By Using QFD and TRIZ Method

Yu Ching Hung[1, *], Yann Long Lee[2] and Seng Yee Von[1]
[1]*Faculty of Mechanical and Manufacturing Engineering Technology, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia.*
[2]*Department of Industrial Design, Chaoyang University of Technology, Wufeng District, Taichung, 413310 Taiwan (R.O.C.).*
**Corresponding author*: mohdhung@utem.edu.my, *ORCiD*: 0000-0003-0143-6634
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***Abstract* —This research paper aims to address several challenges associated with the use of walkers, namely, the problem of incorrect posture leading to physical discomfort, increased product requirements, lack of collapsibility affecting portability, and storage issues caused by the walker's large size. To effectively overcome these challenges, a combined approach of Quality Function Deployment (QFD) and the Theory of Inventive Problem Solving (TRIZ) is employed. The House of Quality (HOQ) is utilized as a tool to analyze the relationship matrix within the HOQ and the characteristics of the product. The TRIZ method is applied, leveraging 39 parameters and 40 Inventive Principles, to solve the identified problems. The concept development phase encompasses various techniques such as hand sketches, a sketchbook, Solidworks, and other pertinent tools. Subsequently, a prototype is developed and subjected to a validation survey. The results of the survey demonstrate a high level of satisfaction among the respondents, indicating that the walker successfully fulfills their requirements.**

Keywords—Mobility aids, Walker, Quality Function Deployment(QFD), Theory of Inventive Problem Solving (TRIZ)

I. INTRODUCTION

Mobility aid is a device that is used by millions of users all over the world but usually, people would not consider it. People with disabilities problem suffering problems that we could not imagine such as inconveniences that happen to their daily life. The growth of population with disabilities will keep increasing year by year [1]. Mobility aids have been used for centuries by people who have problems moving around or those who are recuperating in need of rehabilitation. Nonetheless, the path towards the development of mobility aid has not been an easy one and there are still many shortcomings that need to be discussed and improved.

Walker is one of the most used mobility devices also called as Walking Frame or Zimmer Frame, it was produced in the early 1950s. Moreover, the walker with roller which is called as rollator was invented in the decennary 70's. A rollators are more sophisticated as compared with traditional walker due to the weight of it is lighter and it attached with hand brakes to slow down or stop the movement of the rollator [2].

Furthermore, walker or roller walker consists a risk of falling due to many empirical studies. About 80% of the participants purchase a rolling walker without knowing the proper operation instruction or consultation with a medical expert, 61% of them operate the walker roughly with their own understanding and 19% of users get their walker from medical professionals without any operation instruction. The most commonly occurred problem was incorrect rolling walker height 55%. There were approximately 17% of the rolling walkers have maintenance problems. Besides, 40% of the users would have a forward-leaning posture while standing and use the walker as support and 50% is while using the walker to mobilise. Forward-leaning posture during mobilisation would have a high probability of causing the user falls [3].

Even though the walker brings help to users, but there are some weak points or even risks of injury associated with their use. One of the main problems is that research found that users who used the standard walker would have forward-leaning posture which causes back or neck pain. As the current walker designed with low quality brakes and it commonly

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used to stop the rear wheels of the walker by pressing a bar against the surface wheel, this kind of brake become dangerous when using it in rain and degraded wheel surface over time [4]. Next, regarding the analysis of walkers, the population of elderly will increase which lead to the increment of walker demand, therefore we need to attach great importance to walker and improve it. Lastly, another problem that occurred in the existing walker is the limitation of portability, user would face the problem on carry out the walker which brings inconvenience to them. Apart from that, limited portability would lead to a storage problem, users would face difficulty in situations such as storing the walker in a small space, retrieving walkers after being seated, or using public transportation.

Between 2015 and 2050, the world's old population is expected to grow from 900 million to 2.0 billion, according to WHO (World Health Organization). The requirement for mobility aids is on the way up among the geriatric population due to the benefits that bring to the user such as the purveyance of balance, providing extra support, and the improving ability of users to have their daily activities independently. Furthermore, the demand for rehabilitation equipment is increasing as a result of the important role it plays in improving the lives of the physically challenged. In 2015, walkers accounted for the soaring profit share of 31.65% [5]. Walkers have several advantages over conventional mobility aids, including the ability to improve a user's walking ability, assuring safety and comfortability while walking, and the extra support supplied to the user, as well as the high weight-bearing capability. The need is emphasized further by the incorporation of these walkers into rehabilitation training, which primarily enables daily activity among the elderly or lower limb disabled while rebuilding their muscular strength and assisting in reaching optimal muscle mobility.

This study aims to address the increasing demand for walkers by designing and improving their features to overcome existing limitations. The research objectives are as follows:

1. Enhance user comfort, safety, and minimize the potential side effects associated with walker usage.

2. Address the portability issue by integrating the Quality Function Deployment (QFD) and Theory of Inventive Problem Solving (TRIZ) methods.

3. Design a compact and simplified walker to optimize storage capacity.

By achieving these objectives, this research contributes to the ongoing advancement of walker design, ensuring that it remains responsive to the evolving needs of users and the increasing market demands.

II. METHODS AND IMPLEMENTATION

This project incorporates both the Quality Function Deployment (QFD) method and the Theory of Inventive Problem Solving (TRIZ) method.

A. Quality Function Deployment

QFD was widely used in various fields as it is well known and useful tool for apprehend and fulfil customer requirements and connecting those requirements to design requirements [6]. QFD is used in evaluating and prioritizing particular parts of improvement and then transferring it to the expectable process and product requirements. Besides, QFD has also functioned to bring the personal interface to advanced industry. QFD connects the customer's needs with the supplier's design, engineering, production, and service operations [7]. Besides, House of Quality (HOQ) is one of the matrices of an iterative process for Quality Function Deployment (QFD). It is the nerve center that drives the entire QFD process.

Several studies have demonstrated the effectiveness of Quality Function Deployment (QFD) in improving product design and resolving conflicts. For instance, Yin *et al.* [8] utilized a fuzzy ANP-QFD methodology to identify stakeholders in product-service systems development from an ecosystem perspective. The approach involved a three-stage process, and a case study on the automobile after-market validated the proposed model. Ginting *et al.* [9] conducted a case study on the redesign of a cutting tool and employed QFD to gather customer requirements and incorporate ergonomic perspectives. The study identified critical factors and successfully developed a new design that reduced musculoskeletal complaints, enhancing work quality and usability. In the realm of school furniture, Koleini Mamaghani and Barzin [10] utilized QFD to optimize product design and quality. They employed tools such as the House of Quality (HOQ) matrix and conducted a questionnaire survey involving 160 students from three high schools. The results highlighted the significant impact of seat position on back, neck injuries, and leg pain, indicating its importance to students.

These studies underscore the efficacy of QFD across various domains, including product-service systems, ergonomic design, and school furniture. QFD proves valuable in enhancing product design, differentiating offerings, and effectively addressing user requirements and preferences.

B. Theory of Inventive Problem Solving (TRIZ)

TRIZ, the Theory of Inventive Problem Solving, is a renowned scientific approach that not only helps define and provide solutions but also cultivates creative personality traits and fosters innovative thinking. The fundamental principle of TRIZ is to seek potential solutions based on previously well-solved problems [11].

Developed by Genrich Saulovich Altshuller between 1946 and 1998, TRIZ was initially coined as a Russian acronym. Altshuller recognized the need for a systematic approach that would surpass the trial-and-error method and focus solely on finding solutions. Through extensive analysis of tens of thousands of patents, Altshuller observed that technology adheres to a set of rules. These rules can be studied and utilized to enhance existing systems and discover innovative problem-solving approaches [12]. Altshuller formulated a framework for engineering evolution tendencies and emphasized the significance of identifying and resolving conflicts in overcoming challenging innovation problems. In doing so, he developed the TRIZ postulates, which highlight the fundamental distinction between imaginative thinking and a routine mindset [13].

TRIZ encompasses various widely used methods and tools, notably the 40 Inventive Principles and the 39 Technical Characteristics and Conflict Matrix, which are elaborated upon below.

The 40 Inventive Principles were derived from an extensive analysis of 40,000 patent inventions [14]. The findings of this study unveiled a recurrent pattern, demonstrating that a significant majority of the inventions employed these principles. The 40 Inventive Principles serve a dual purpose as a catalyst for fostering creative thinking and as a compass for identifying optimal design solutions. The framework of the 40 Inventive Principles Management System is centered around the resolution of technical contradictions, encompassing innovative awareness and conflict resolution processes.

Addressing the improvement of system characteristics, the 39 Technical Characteristics and Conflict Matrix technique seeks to tackle situations where enhancing certain aspects of a system inadvertently hampers other technical facets, resulting in technical conflicts during the problem-solving process. Employing a conflict matrix system, this methodology aims to address and reconcile conflicts by scrutinizing the relationship between conflicting characteristics in matrix form [11].

C. Related Researches

The integration of the Quality Function Deployment (QFD) methodology and the Theory of Inventive Problem Solving (TRIZ) has proven to be a robust approach in problem-solving and innovation within various domains. QFD is a structured technique that links customer requirements to design and engineering parameters, facilitating the development of products that align closely with customer needs. TRIZ, on the other hand, is a systematic innovation methodology that provides tools and principles to identify inventive solutions to complex problems.

According to recent studies, this combined approach has demonstrated remarkable effectiveness in addressing identified challenges. For instance, a notable study conducted by Naveiro and de Oliveira [15] presented a model aimed at enhancing the engineering requirement system through the integration of the Quality Function Deployment (QFD) and TRIZ methods. This investigation involved the direct extraction of requirements from patent documents, intending to identify prevalent user interconnections via the QFD matrix. Subsequently, inconsistencies in user needs were addressed by employing the TRIZ Contradiction Matrix, which harnessed innovative principles to formulate the final product concept. Furthermore, another relevant work, titled "Creative Product Design of Intangible Cultural Heritage of Yi Nationality," authored by Chen *et al.* [16], followed a similar methodological approach as aforementioned.

Subsequently, Zhang and Li's [17] subsequent study focused on refining the interaction design of aging smart home products through QFD and TRIZ integration. They began by extracting requirements from the elderly demographic and categorizing data into physiological, psychological, and interactive prerequisites. This informed the construction of a customized House of Quality (HOQ) for smart home products, facilitating an in-depth relationship matrix analysis and redundant attribute identification. To counter negative correlations in the Auto-correlation Matrix, the researchers adeptly applied TRIZ theory to resolve product characteristic conflicts. Li *et al*. [18] introduced a user-centric approach to smart vessel alarm system design, seamlessly combining TRIZ and QFD frameworks to alleviate alarm fatigue. Their methodology aimed to enhance system-operator interaction, rooted in comprehending user requirements derived from insights by VTS personnel. The process comprised three phases, strategically involving QFD, TRIZ, and software quality attributes. Beginning with extracting user needs from operational procedures, progressing to addressing non-functional design requisites, and identifying inconsistencies, the final phase engaged in detailed inventive principle analysis through the contradiction matrix.

Similarly, Xi and Meng-di's [19] study, "Research on Wheelchair Design for the Disabled Elderly Based on QFD/TRIZ," fused QFD and TRIZ methodologies to enhance mobility aids for seniors with disabilities, mirroring the theme of this investigation. Their inquiry began with a deep understanding of the target demographic's needs. Assessing limitations in QFD and TRIZ theories, they formulated an integrated model, resulting in a redesigned wheelchair addressing multifaceted challenges faced by disabled seniors, in alignment with user needs. This integrated model demonstrated its potential in crafting functional designs for handicapped seniors, substantiated by an extensive exploration of the design process and its outcomes.

Therefore, the amalgamation of QFD and TRIZ emerges as a powerful methodology for tackling intricate issues and fostering innovation. These methodologies harmoniously blend customer-centricity with systematic inventive thinking, culminating in heightened efficacy for problem-solving and product development. In this study, the fusion of QFD and TRIZ will be employed to both design and enhance the walker.

D. Implementation

The research workflow is divided into four stages, each of which serves a particular role in the overall process. The first stage, current market products and problem description, is dedicated to gaining thorough project-related information. This stage requires collecting product specifications from the present market and identifying difficulties and requirements of the consumer. The collected data is then analyzed using specification analysis to get insights into existing market products and consumer requirements.

The second stage is data analysis. This stage comprises efficiently analyzing and planning user requirements while also gaining a better understanding of their specific requirements. This is accomplished through the utilization of a questionnaire survey. The questionnaire is designed to gather the voice of customer (VOC), which will subsequently assess user needs. The survey results are then utilized to build the House of Quality (HoQ). The HoQ is an advanced QFD approach for data categorization and establishing an obvious connection between consumer requirements and product features.

The third stage centers around product development. Once the data have been thoroughly analyzed, the TRIZ method is employed to address any identified negative correlations within the HOQ. Concept development activities are then initiated, followed by the creation of a detailed 3D model and its rendering using SolidWorks software. These steps ultimately culminate in the finalization of the product design.

Lastly, the fourth stage focuses on design validation and result attainment. During this phase, prototype creation and refinement processes are undertaken to ensure that the desired outcomes are successfully achieved and validated. Through iterative improvements, the final design that fulfills user requirements is attained.

III. RESULT AND DISCUSSION

A. *Existing Products in the Market and Problem Definition*

A mobility aid is a device designed for people who is facing the problem of mobility or otherwise improve mobility. There are various mobility aids such as walkers, canes, white canes, forearm crutches, manual wheelchairs, electric wheelchairs, motorized scooters, etc. [20]. This paper primarily focuses on the design and improvement of walkers.

Inexperienced designers may sometimes struggle to grasp the intrinsic nature of their product and its contextual integration within the market landscape. Specification Analysis is a critical step in this study. Therefore, before beginning this research and project, designers must gather data for specification analysis and product positioning. First, a comprehensive specification analysis was conducted (see Table I) to examine the various available walker configurations that can be purchased through healthcare suppliers, pharmacies, or online platforms in the market. It is essential for users to select a walker that is tailored to their specific needs and requirements. The use of position maps facilitates market assessment, enabling designers to understand market trends and narrow down user requirements. This ultimately culminates in a comprehensive understanding attained through the morphological chart's systematic disassembly and deconstruction approach.

This section specifically addresses a set of twenty walkers, and the results of the specification analysis are discussed in detail. The analysis provides a comprehensive overview of the products, including their names, brands, prices, weight capacities, and other relevant details. In Table I, the left side is the basic specification, and the right side is described based on what designers discuss and analyze. To designers, by thoroughly examining this information, a better understanding of the walkers and their attributes, structure, materials, functions, and problems is achieved, which in turn facilitates the process of enhancing walker design and performance.

Table I: Sample of specification analysis.

No	Product	Description
1.	 Karman R-3600 three-wheel rollators Source: karmanhealthcare.com Place of manufacture: United State Brand: Karman Price: 85 US dollars (RM346.29) Weight capacity: 113 kg Net weight: 6.8 kg Product Size: 89-104 cm (overall height); 56 cm (overall length); 64 cm (overall width) Brake style: Loop brakes	**User / Situation:** Elderly, Patient, Lower extremity patient, Outdoor, Shopping, or other public interior space **Function** Long-term life assistance(always) **Operating Instruction:** ● Check the walker, step into it from the back, and push it forward at the same time. ● Treat the brakes to slow down and stop, or lock them in place, to prevent the walker from rolling away inadvertently. **Structure:** Walker with three wheels in a triangle shape to improve the speed. **Features:** ● Adjustable ● Ergonomic design perspective ● Easy to store ● Need some space. **Potential Problems:** ● User is easy to make mistakes ● Wheel skidding

B. *Survey of User Requirements*

Following a comprehensive analysis of existing products and market conditions, the problem statement for this study was formulated. It was observed that incorrect posture during walker usage often results in discomfort and body pain. Furthermore, the increasing demand for walkers is hindered by their inadequate collapsibility, leading to storage challenges. In order to validate these observations and gain valuable insights into user requirements, a questionnaire survey was conducted. Google Forms was selected as the platform for survey administration due to its user-friendly interface. The target user group for walkers encompassed individuals with various conditions such as lower limb weakness, lower limb disability, and visual impairments. To ensure the relevance of the obtained insights, respondents were specifically chosen from hospital or clinic patients, representing the intended user demographic.

The questionnaire survey involved 50 experienced users of walkers for long-term transportation. It consisted of three sections: Section A collected basic information, Section B focused on general knowledge of walkers, and Section C utilized a Likert scale to assess opinions on walker specifications. The survey spanned a duration of one month and utilized Google Forms as the data collection platform, particularly suitable during the ongoing pandemic. Respondents were approached in diverse locations, including hospitals, pharmacies, and old folk homes, with a majority of respondents originating from Sehat Healthcare Centre in Seremban. The inclusion of professionals from pharmacies, specialty stores, and medical staff enriched the survey by providing valuable insights from their respective perspectives.

Based on the analysis of the survey results, several criteria were selected for further design direction. These criteria include "Safety," "Adjustability," "Comfortable," "Foldable," and "Portable." The following points summarize the design direction based on these criteria:

1. The design of the walker should cater to the needs of senior citizens.
2. The walker should provide stability to support users with lower limb weakness.
3. It should be foldable and portable to facilitate both indoor and outdoor use.
4. Ergonomics should be considered to prevent body pain and ensure user safety.
5. The design of the walker wheels should prioritize stability and safety, as many users tend to avoid wheeled walkers due to concerns about unreliable wheels and brakes.

These findings from the preliminary survey indicate that the product has specific issues that require attention and consideration in the subsequent stages of the project.

C. Development of HoQ

Following the analysis of user requirements, a comprehensive list of customer requirements was identified, and a corresponding set of technical requirements was developed. These findings were then integrated into the construction of the House of Quality (HoQ). The HoQ utilized symbols positioned at the center to indicate the relationship between customer requirements and technical requirements. At the top of the HoQ, a correlation matrix was employed to assess the strength and nature of the relationship between each requirement, categorized as strong positive, positive, neutral, negative, or strong negative. Technical goals were specified at the bottom of the HoQ, aligning with the technical requirements.

The chart in Fig. 1 is essential for constructing the "House of Quality" as it represents the "voice of the customer" and facilitates the comparison and summary of design requirements. The customer requirements, also known as "Whats," were obtained through a survey conducted earlier, ensuring the elimination of any redundancies. The importance of each customer requirement was rated on a scale of 1 to 5 based on the survey results. Requirements rated below 4.5 were assigned a rating of 2, below 4.6 a rating of 3, below 4.7 a rating of 4, and above 4.7 a rating of 5, as indicated in Table II. For instance, the "Safety" requirement had an average rating of 4.74, resulting in an importance rating of 5, while the "Feature" requirement had an average rating of 4.46, yielding an importance rating of 2. The next step involved determining the percentage of priority by summing up the priority ratings (totaling 44) and calculating the percentage for each customer requirement. For example, the "Adjustability" requirement, with a rating of 4, would be divided by 44, multiplied by 100%, resulting in a priority percentage of 9%.

Customer Requirement	Priority rating out of 5	Priority percentage (%)
Safety	5	11
Adjustability	4	9
Comfortable	5	11
Foldable	4	9
Portable	5	11
Function	2	5
Price	3	7
Quality	3	7
Easy to use	4	9
Easy to store	4	9
Feature	2	5
Ergonomic	3	7

Fig. 1. Customer requirement.

Table II: Importance rating.

Average Rate	Importance
≥ 4.7	5
≥ 4.6	4
≥ 4.5	3
≥ 4.4	2
< 4.4	1

After the clarification of customer requirements, a corresponding list of technical requirements referred to as the "Hows," was developed (Fig. 2). This list demonstrates how the technical aspects can influence the fulfillment of the customer-identified requirements. For instance, achieving portability for the walker may involve reducing its weight, while ensuring safety necessitates the selection of high-strength materials. At the top of the House of Quality (HoQ), a correlation matrix is positioned to assess the relationship between each requirement, denoted as strongly positive, positive, neutral, negative, or strongly negative. For example, a decrease in the weight of the walker would strongly correlate with its ease of carrying, indicating a strong positive correlation between "lightweight" and "easy to carry." Conversely, an upright design typically impedes portability, resulting in a strong negative correlation between "upright design" and "easy to carry." It is important to note that interdependencies may exist between technical requirements, further complicating the process. Additionally, the bottom row of the correlation matrix employs triangle-shaped symbols to indicate whether a particular requirement should be increased or decreased.

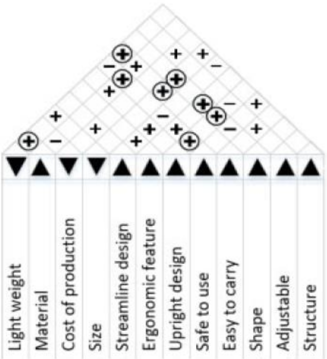


Fig. 2. Technical requirement.

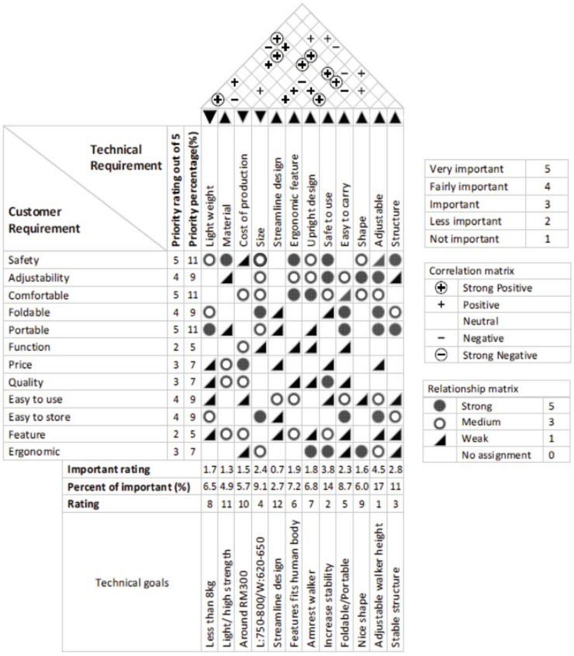


Fig. 3. House of Quality.

Ultimately, a House of Quality specific to the walker design was created, as illustrated in Fig. 3.

D. TRIZ Problem Solving

By utilizing the House of Quality developed in the previous sub-topic, the correlation matrix of the technical requirements was generated and examined for negative correlations. These negative correlations serve as the focal points for applying the TRIZ (Theory of Inventive Problem Solving) methodology.

Negative correlations can be categorized into two types of contradictions: technical contradictions and physical contradictions. Technical contradictions arise when the properties of the entire technical system are involved. For example, the characteristics of "Safe to use" and "Simplistic" are related to the reliability and complexity of the walker, thus presenting a technical contradiction. On the other hand, physical contradictions are associated with the physical properties of specific elements within the system. For instance, the characteristics of "Upright design" and "Adjustable" pertain to the length of a particular part of the walker and its volume, constituting a physical contradiction. By recognizing and resolving these types of contradictions, the issues with the walker can be systematically addressed, facilitating the design process.

Table III: TRIZ problem transformation for conflict problems.

Negatively related characteristic	39 General Engineering Parameters	Type of Contradiction
Light weight	2. Weight of stationary object	Technical contradiction
Safe to use	27. Reliability	
Safe to use	27. Reliability	Technical contradiction
Simplistic	36. Device complexity	
Simplistic	36. Device complexity	Physical contradiction
Structure	29. Manufacturing precision	
Upright design	Length of stationary object	Physical contradiction
Adjustable	6. Volume of stationary object	
Safe to use	Reliability	Physical contradiction
Shape	Shape	

Following the identification of negatively related characteristics and the establishment of the correlation matrix, 39 general engineering parameters were employed to eliminate the negative correlations. The outcomes of this process are presented in Table III. Subsequently, 40 inventive principles were applied to offer potential solutions for each matched parameter. For instance, the first negative correlation identified between "Safe to use" and "Light weight" corresponds to parameter No. 2 and No. 27. Through analysis, three principles—"Antiweight," "Preliminary action," and "Mechanics substitution"—were found to be applicable in addressing this negative correlation. It is important to note that not all three principles need to be utilized; the selection of the most suitable principle depends on the specific problem at hand, as these principles serve as general guidelines. Table IV presents the corresponding principles for five negative correlations, providing further insights into the problem-solving process.

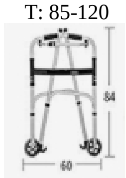
E. Concept Design and Development

The TRIZ 39 matrix and 40 principles were used to generate solutions and design directions for the walker. These solutions will be incorporated into the design and development process. A morphological chart was used to analyze the walker in detail, and the solutions from TRIZ will be incorporated into the morphological chart to identify suitable parts and improve them based on the innovation principles.

Table IV: TRIZ problem solution.

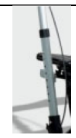
Negative correlation	The corresponding TRIZ theory of the solution.	Type of Contradiction
1	10. Preliminary action - Perform, before it is needed, the required change of an object (either fully or partially).	Technical contradiction
2	1. Segmentation - Make an object easy to disassemble. 13. The other way round - Make movable parts (or the external environment) fixed, and fixed parts movable.	Technical contradiction
3	2. Taking out - Separate an interfering part or property from an object, or single out the only necessary part (or property) of an object.	Physical contradiction
4	7. Nested doll - Place one object inside another; place each object, in turn, inside the other. - Make one part pass through a cavity in the other.	Physical contradiction
5	16. Partial or excessive action - If 100 percent of an object is hard to achieve using a given solution method, then, by using 'slightly less' or 'slightly more' of the same method, the problem may be considerably easier to solve.	Physical contradiction

Table V: Idea for product feature.

	Product Feature	Design Direction	Analysation
1	Foldability	Foldable	Foldable walker to reduce it's size by making the height of walker shrinkable.
	Break System		Hand-brake that connected directly to the wheels of walker to allow user have timely brakes to ensure their safety.
2	Size(mm)	L: 520-550 W: 600-630 H: 1050-1210 	Walker design would be armrest walker to solve the posture issue.
	Size -Fold Size (mm)	T: 85-120 	Walker aimed to have a folded size of 85-120.
3	Structure Style	Rectangular shape 	Walker structure would have the element of rectangular shape to increase stability.

…	…	…	…
6	Fold Structure	Square	Easy to be store

Table VI: TRIZ solution analysis.

	TRIZ Solution	Solution Description	Design Sample
1	**10. Preliminary action** -Perform, before it is needed, the required change of an object (either fully or partially).	-The body of the walker could not use the solid form; big hollow tube could reduce the weight yet increase the stability.	 Hollow tube
2	**1. Segmentation** -Make an object easy to disassemble. **13. The other way round** -Make movable parts (or the external environment) fixed, and fixed parts movable.	-To make sure the walker has a streamline and simplistic design, walker should be easy to assemble and disassemble. - By making the movable part fixed could increase the stability even though it's streamline design.	 Walker part fixed
3	**2. Taking out** -Separate an interfering part or property from an object, or single out the only necessary part (or property) of an object.	-The structure of the walker, as depicted in the image on the right, exhibits a streamlined design.	 walker structure
4	**7. Nested doll** -Place one object inside another; place each object, in turn, inside the other. -Make one part pass through a cavity in the other.	- The height of the walker can be reduced, as illustrated in the image on the right.	 Button form
5	**16. Partial or excessive action** -If 100 percent of an object is hard to achieve using a given solution method, then, by using 'slightly less' or 'slightly more' of the same method, the problem may be considerably easier to solve.	-The square shape of walker is known to be most stable walker shape, but the design is dull. -Therefore, the walker design could partially keep the element of square shape.	 Square shape walker

As shown in Table V, the morphological chart was used to determine suitable attributes for the walker, such as foldability, wheels, and a handbrake system. The walker's rectangular structure addresses stability concerns, and a four-wheeled design was chosen for its advantages of user balance and weight distribution. Front wheels with integrated brakes and a padded hand grip enhance user experience. The armrest features sponge padding for user comfort, and oxford fabric is suitable for seat and storage bag usage. A seat is incorporated to alleviate outdoor use concerns, and the wheel configuration balances maneuverability and stability on uneven terrain. The foldable structure's square shape optimizes space efficiency, facilitating storage in confined areas.

The walker design solutions, incorporating specific principles, are described to exemplify their conceptual implementation. Detailed descriptions and design samples of the walker are provided in Table VI to illustrate the application of these solutions visually.

Among the generated design concepts for mobility aids walkers, three options stand out: Gofree Walker, Versatile Walker, and BiU Walker. Figure 4 showcases the conceptual sketches of the Gofree Walker (Design concept 1), a portable and foldable walker. Notably, this design incorporates curved tubes on both sides, offering enhanced support to the user. Furthermore, the inclusion of larger front wheels ensures smooth maneuverability even on uneven surfaces. To provide additional convenience, the walker is equipped with a lift-up sit pad for resting purposes.

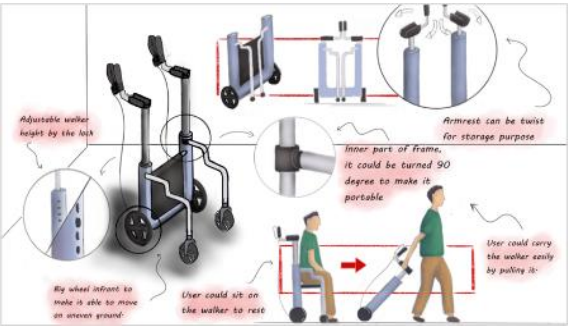


Fig. 4. Concept 1 Design Sketches.

Design concept 2, is the Versatile Walker. It provides excellent help to persons who require more support when walking. Its distinguishing feature is its dual functionality, which allows users to utilize the walker in two distinct modes. Users may use the walker in an upright position by simply flipping down both armrests and locking the wheels. Furthermore, the walker's adjustable height accommodates people of different heights, increasing its adaptability and usage. The BiU Walker, concept design 3 is essentially made up of two huge U-shaped square tubes, which serve as its distinctive feature. Users may effortlessly fold the two U-shaped tubes inward to store or transport the walker. Equipped with four rollers positioned at its base, the BiU Walker includes a side brake that users can engage to prevent movement. Notably, the streamlined design of the BiU Walker sets it apart as a portable option, effectively reducing its weight and ensuring user-friendly operation. As a result, it is well-suited for individuals across diverse demographics.

F. Final Design Selection

Additionally, Fig. 5 presents a three-dimensional model of the walker, generated using Solidwork software, further enhancing the visualization of the design. The final selection of the most suitable concept will be determined using the Pugh matrix, as depicted in Table VII.

Fig. 5. Final design rendering.

Table VII: Pugh Matrix Chart.

No.	Design Concepts / Selection Criteria	Important Rate	W.	 C.1	 C. 2	 C. 3
1	Light weight	8	6.5	0	-	-
2	Low cost of Production	10	5.7	0	0	0
3	Small size(folded)	4	9.1	0	+	0
4	Streamline design	12	2.7	0	0	+
5	Ergonomic feature	6	7.2	0	-	-
6	Upright design	7	6.8	0	0	0
7	Safe to use	2	14	0	-	-
8	Easy to carry	5	8.7	0	0	-
9	Nice shape	9	6	0	0	+
10	Adjustable	1	17	0	0	0
11	Structural	3	11	0	+	0
	SUM (+)				2	2
	SUM (-)				-3	-3
	Total				-1	-1

G. Prototype Making

The fabrication of the walker prototype was completed within a period of one month. The completed prototype is depicted in Figs. 6 and 7.

For the main body of the walker, PVC pipe was utilized as a cost-effective alternative to aluminum tubing, thereby reducing production costs. The armrest of the walker was constructed using a C-shaped elbow as the base, with sponge material incorporated for inner padding and a leather covering for a smooth surface finish. Similarly, the seat pad was crafted with a wooden base, sponge material for cushioning, and a leather covering for enhanced comfort and durability.

In instances where certain parts posed challenges for fabrication or modification, advanced manufacturing techniques such as 3D printing were employed. This enabled the production of intricate components such as the handgrip and brake lever, ensuring precise and customized manufacturing.

Fig. 6. Prototype of the Gofree Walker.

Fig. 7. Prototype of the Gofree Walker (folded mode).

H. Design Validation

After the prototype making, a validation survey was conducted to assess the Gofree Walker's alignment with customer requirements. The survey, administered via Google Forms over two weeks, involved participants from Sehat Health Care Centre. Respondents were instructed to do a little experiment with the walker and offer feedback on its usefulness. The survey questionnaire was divided into four sections: general information, thoughts on the walker, post-test feedback, and overall satisfaction. Section A gathered basic information from respondents, while Section B centered on their thoughts on the walker's look, features, function, and design. Section C included a feedback form with rating scales and 20 assessment criteria, allowing respondents to rate the walker's performance in a variety of ways.

The validation of the questionnaire provides useful information about the level of satisfaction with the designed walker. Overall, respondents showed pleasure with function, design, inventiveness, aesthetics, quality, features, materials, ergonomics, durability, size, and foldability (Fig. 8).

Section A of the questionnaire found that female respondents outnumbered male respondents. A sizable proportion of the responders were above 60 years old, with many being retirees or housewives. Section B results showed that 86.7% of respondents supported the idea and concept of the Gofree Walker. Safety, adaptability, comfort, foldability, and portability were all highlighted in the prior questionnaire survey. The validation investigation verified high satisfaction percentages for these parameters, with acceptable evaluations for safety (86%), adaptability (92%), comfort (86%), foldability (86%), and portability (86%). As a result, it is possible to conclude that the Gofree Walker design effectively fits the needs of the consumers and that the customers have been satisfied with the design.

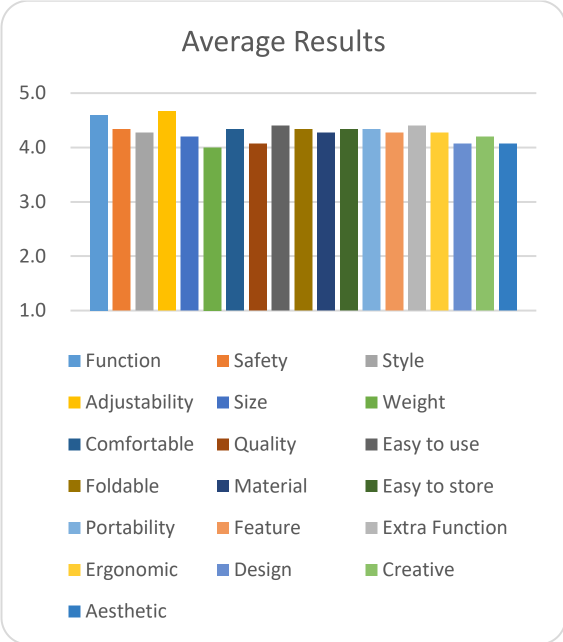


Fig. 8. Average result.

However, certain criteria received lower satisfaction percentages, indicating room for improvement. Design (80% satisfaction), aesthetic (80% satisfaction), and weight (78% satisfaction) were areas where respondents expressed less satisfaction compared to other criteria. These findings suggest that further enhancements can be made to the design and appearance of the walker. Additionally, efforts can be focused on reducing unnecessary components to decrease the overall weight of the walker.

IV. CONCLUSION

The integration of Quality Function Deployment (QFD) and the Theory of Inventive Problem Solving (TRIZ) in this study significantly contributes to the improvement and design of the walker, effectively reducing the associated difficulties. The House of Quality (HOQ) proves to be a valuable graphical tool for identifying relationships among requirements and interactions between the technical aspects of the walker. The implementation of the TRIZ method, encompassing 39 engineering parameters and 40 inventive principles, successfully overcomes the limitations of QFD. Various tools such as preliminary surveys, specification analysis, market positioning analysis, and the Pugh matrix are employed to achieve the objectives of this research. Furthermore, a validation survey confirms that the walker meets user satisfaction.

There are abundant opportunities for further improvements and design enhancements in the realm of walkers. Given the challenges posed by the ongoing pandemic, it is advisable to increase the number of survey respondents to ensure a more robust and representative sample. Efforts can be made to streamline the manufacturing process, thereby reducing costs for end-users. The design and aesthetics of the walker may benefit from further refinement, incorporating more creative structures or features. Additionally, the integration of smart technology in the product development of walkers could be explored to transform them into smart mobility aids.

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