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Application of TRIZ Innovative System Method in Rapid Assembly of Folding Chairs

Kai-Chao Yao [1], Kuo-Yi Li [2,3], Jing-Ran Xu [1,4,*], Wei-Sho Ho [1,5,*] and Yu-Hao Shen [1,6,7]

[1] Department of Industrial Education and Technology, Bao-Shan Campus, National Changhua University of Education, No. 2, Shi-Da Road, Changhua City 500208, Taiwan
[2] Department of Industrial Engineering and Management, National Chin-Yi University of Technology, No. 57, Sec. 2, Zhongshan Rd., Taiping Dist., Taichung City 411030, Taiwan
[3] Society of Innovative Education and Technology, No. 164-1, Yanji St., Da'an Dist., Taipei City 106062, Taiwan
[4] Sheng Jen Industrial Co., Ltd., No. 49, Aly. 2, Ln. 226, Sec. 1, Zhongzheng Rd., Changhua City 500004, Taiwan
[5] NCUE Alumni Association, National Changhua University of Education Jin-De Campus, No. 1, Jinde Rd., Changhua City 500207, Taiwan
[6] Department of Intelligent Production Engineering, National Taichung University of Science and Technology, No. 129, Sec. 3, Sanmin Rd., North Dist., Taichung City 404336, Taiwan
[7] Department of Business Administration, National Chin-Yi University of Technology, No. 57, Sec. 2, Zhongshan Rd., Taiping Dist., Taichung City 411030, Taiwan
* Correspondence: a047224716@gmail.com (J.-R.X.); homaintain@gmail.com (W.-S.H.)

Abstract: This design activity is an innovative method of rapid assembly system for folding chairs. The research methods used in this study included literature analysis, TRIZ the method, human factors engineering (HFE), universal design, and IPA. First, the design of the folding chair and the layout of the literature related to the chair are analyzed. The contradiction matrix was used in the TRIZ method to find the principle of invention and analyze it, to provide a reference for the innovative design of folding chairs, and then use the relevant literature on materials to help design and select materials quickly. Next, the chair is assembled and unfolded and universal design is applied to design it into an acceptable product, causing it to be more popular. The human–machine interaction with HFE makes the design of rapid assembly and the design of folding chairs faster and safer. Finally, the IPA method is used to understand the subjective feelings of customers on the products of this research and the satisfaction and importance are used as the basis for evaluation; a two-dimensional matrix graph is drawn. After drawing a simulation using drawing software, it is compared with the traditional folding chair and the research results are as follows: (1) Quick unfolding function: use the pull ring upwards and it naturally unfolds downwards by gravity. (2) Quick folding and storage function: use the foot pedal, single-foot operation, and the folding chair can be quickly stored. (3) Rapid transportation and unfolding function: The chair back can be connected with other chair backs and has the functions of quick unfolding and quick storage, so as to realize the quick placement of the folding chair. This design activity realizes the preliminary design concept and design simulation of the product design through a systematic and innovative method. Through this design activity, we can understand the problems existing in product improvement before product development, so as to conduct market research and production cost assessment in the actual mass production later, and further reduce the cost of product design improvement.

Keywords: folding chair; exhibition chair; TRIZ; human factors engineering design; universal design

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1. Introduction

Folding chairs are everywhere in our daily life, from small outdoor camping picnics to medical institutions, school classrooms, community centers, sports venues, football fields, exhibition booths, and more. Foldable furniture is a trend in the modern furniture industry. Many folding chairs need to be placed and arranged for VIPs visiting venues and

exhibits. Exhibitors are required to arrange folding chairs in a row, side by side. Personnel are required to carry a chair with them and unfold them one by one. They need to be aligned one by one after being placed. The repeated bending action and unfolding design of the folding chair have a lot to do with human safety. Additionally, there is a strong, positive, and significant correlation between space-saving effectiveness and ergonomic performance [1]. During repetitive and highly repetitive work that uses the same part of the body, the recovery from muscle fatigue cannot keep up with the frequency of exertion, exceeds the load on the body, and accumulates the resulting musculoskeletal buildup, which is one of the most common reasons for injuries. It is more common in manual-intensive work environments, such as office typing, housework, and assembly workers [2].

In addition, when the spine is subjected to eccentric loading or torsional loading, the disc may experience microtrauma; repetitive small injuries may cause cracks in the annulus, resulting in structural abnormalities. Finally, the nucleus pulposus erupts and causes herniation of the intervertebral disc (HIVD) [3].

According to the cause of death statistics for children and adolescents from the Social and Family Affairs Administration of the Ministry of Health and Welfare, about 2 out of 1000 children and adolescents die each year from chair-related accidents [4]. When the folding chair is unfolded, it will be dangerous because of its own inattention. For example, in the case of a student in the Nanyuan Elementary School in Taoyuan, when the student uses the folding chair, he inserts his finger into the round hole on the seat, but when he wants to withdraw it, he explains: "When I got stuck, I was mad, but the harder it was, the harder it was to get back. With the help of my classmates, I was looking for the guidance of the training director who was working at the time". The Pingzhen fire brigade found four police officers to assist and another five people. After they struggled with the chair for more than a minute, it finally and safely freed the fingers of the boy named Zeng [5]. However, the above case is relatively lucky, as the child was only slightly injured. However, in recent news reports, folding chairs have caused the deaths of two children, aged 3 and 8 years old, respectively [6,7]. In order to avoid more regrettable incidents such as these, this design activity focuses on the development and evaluation of a fast, convenient, and safe folding chair. Additionally, the TRIZ contradiction matrix and innovation evaluation form are used to prove that this product has a certain novelty.

2. Discussion of the Literature

This design activity mainly discusses the arrangement and placement of folding chairs in exhibitions, the convenience and safety of the user, and the repetitiveness of the body for long-term alignment. The first step is to collect the literature on seat design and related materials and repetitive force injuries. The literature is analyzed and used as a basis for research. According to the literature, the paper further analyzed the innovative design of the folding chair, the innovative design of the folding chair, the rapid design of the folding chair, and the innovative design of the folding chair for quick handling and deployment. Finally, the innovative design with the TRIZ method, human factor engineering method, and general design method is used as the basis of the third chapter research design, which is described in detail below.

2.1. Literature Review on Seat Design and Related Materials

In today's society, the seat is an inseparable item in our lives. Whether it is going to work, recreation, or commuting, it is related to the seat. Therefore, when designing the seat, it is necessary to explore the comfort to avoid spinal injury or back pain. The function of the backrest is mainly to provide the lumbar vertebrae and the back support of the human body. The support position is about the depression below the center of the waist and the back and the support of the neck and the head is provided, with the backrest angle between 95° and 100°. A lot of comfort is needed [8]. People's body size ratios are different and their work is different. The design is designed with the comfortable angle of the public. The most comfortable angle of the seat is about 100 degrees. In the general formal position, the

seat back, and the seat, the angle is designed to be close to vertical and the seat rest needs to be large. If the angle between the back of the seat and the seat is more than 120 degrees, the muscles of the human body are almost completely unstressed, so, for the ideal desk, the back angle of the chair back must be 90–100 degrees, no more than 120 degrees [9].

The materials used to manufacture chairs include wood, plastic, metal, etc. Wood is a hard material with fibrous tissue that can be shaped into wooden panels, but it is thicker and more expensive than alternatives. Plastic is the most widely used material in the manufacturing industry, using synthetic chemicals to form materials with high molecular organic polymers such as PVC, PE, PET, etc., which have superior corrosion resistance and chemical resistance. Metals are elements, compounds, or alloys that are good conductors of electricity and heat, and are usually ductile and shiny, reflecting most natural light. For example, aluminum alloy is lighter in weight and more convenient to transport [10].

The folding chair design includes a folding structure, which belongs to a structure that is deployed in time and is folded when not in use. It is divided into a fully folded state and a fully expanded state. Different structures may influence its appearance, material, function, operability, etc. There are differences. The casual portable folding table and chair are designed to provide a convenient folding table and chair, which is small in size and easy to carry [11]. Most foldable chairs today require it to be anywhere and light and there is a trend for adding more features and other designs.

2.2. Repeatability Causes Damage

In recent years, terms such as Repetitive Strain Injury and Cumulative Trauma Disorders have been widely used and Carpal Tunnel Syndrome, Tennis Elbow, and Quebec Nouns such as deQuervain's disease are used to indicate joint pain, which is very troublesome and easy to relapse, often seriously affecting the quality of life [7]. RSI can be considered a chronic pain, but many of the features of RSI differ from the more general discussion of chronic pain [12].

2.3. TRIZ Method Literature Discussion

TRIZ is a knowledge-based system invention problem solving method [13] that provides a systematic approach to finding technical solutions and improving the innovation of technical systems [14]. The method was created by the Russian scholar G. Altshuller in 1946 to obtain ideas for solving general problems. Its purpose is to organize any controversial points about the concessions that appear in the problem gap by focusing on the identification of the research [15]. Regarding the spread of TRIZ, the fall of the Soviet regime allowed it to spread outward to other countries, especially thanks to the transfer of some of Archishuler's collaborators in North America, Europe, and East Asia. In fact, TRIZ has been taught in universities since the 1990s and has been adopted by leading companies in 35 countries [16]. Large multinational companies immediately recognized its benefits [17] and perhaps Samsung represents one of the best cases of TRIZ adoption in the industry [18,19]. Recently, many companies have attached great importance to the training of employees' innovations and creativity. The techniques for stimulating creative thinking include two methods: (1) Analytically oriented—follow certain steps, structures, and sequences to guide the inventor to expand the solution space, commonly used methods include induction and deduction. (2) Intuitively oriented—using patterns or symbols, using associations to stimulate the inventor's solution space. Commonly used innovative methods are the TRIZ method, brainstorming method, 635 creative method, solo brain storming, gallery method, and Delphi method, among which the TRIZ method is currently used in the industry [20].

The TRIZ method can also be successfully used to understand and solve complex management problems. Before a new installation solution designed for the ultrasonic welding automation workspace is put into production, they will be verified by computer simulation to test their mechanical properties and other optimizations will be carried out [21]. The practical application of TRIZ in technology is that there must be some

professional versions of TRIZ that differ in the naming and content of information assets and the same goals set for the construction industry [22]. Employees with a high degree of engagement and highly developed creativity and innovation can help companies build innovative products and services to gain a market position. This process is a positive application of methods and tools that influence the innovative approach TRIZ [23]. The TRIZ solution is basically solving the problem of "creative", including the problem of "demand conflict", which is called "contradiction". At the same time, he also found that the basic principles for solving these problems have been repeatedly used, so his thoughts are summed up by the commonality of these inventions, the repetitiveness, and the thinking logic of innovative inventions [14,24,25].

Lin and Wang used the common product experience between pet cats and their owners as the starting point for the product design, enhancing the usability of cat food bowls and improving the pet cats' eating habits. The TRIZ method was also found to provide clear directions and shorten the development time in the product development process [26]. For example, by applying the TRIZ theory to explore cleft lip and palate makeup concealers, Yan et al. used 40 invention principles and 39 engineering parameters as the basis for identifying the problem and presenting abstract beauty using different types of makeup techniques in concrete terms. They chose to analyze and study the techniques of Japanese, European, and American makeup applications and combined the techniques with TRIZ to achieve the corresponding balance between them [27]. Weng and Chen used parts of some TRIZ tools such as 39 engineering parameters, 40 invention principles, and 76 standard solutions to solve the brake problems of typical motorcycles and mopeds on rainy days and to improve driving safety [28]. Chen and Ho combined value engineering and TRIZ in their study of floating piers. They used three-way floating piers as their example, with completed construction as references. The research results obtained from the study of the floating piers found that they can save about TWD 23 million, or 28% of the original cost of TWD 82 million, and serve as a reference case for the design, cost analysis, and value engineering study of floating piers to be built in the future [29].

2.4. The Human Factors Engineering Literature

In the early days of the United States, the human factors project was Human Engineering. In Taiwan, some scholars originally translated it into ergonomics. Now, it has gradually declined. The name Human Factors Engineering is replaced by Human Factors, so in Chinese it is also translated into Human. Due to engineering or human factors [30], ergonomics (HFE) is defined as a unique and independent discipline from a unified perspective, focusing on human-human interactions in the essential science, engineering, de-sign, technology, and management perspectives of human-compatible systems [31]. The development of human factors engineering has evolved from the perspective of individual emphasis in the past to the current macro-human project focusing on situation and organization as the main body [32].

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, personnel must be fully integrated into the system [33]. Human factors engineering hopes to adapt to human operations by work, rather than adapting to work by people. However, many medical systems are not designed to perfection. They are often checked by operators to ensure correctness. Operators are constantly changing. In the environment, the use of system design such as software and hardware to perform medical care and the occurrence of illness events are often related to unsafe design, operation, and behavior in the system [34]. The systematic application of a people-centered approach helps ensure that operators and other users are familiar with changes and are proficient in introducing new technologies and that human error is substantially reduced. The combination of HFE methods is critical for determining safety hazards because they relate to the multifactorial characteristics of

the process, i.e., the relationship between humans, technology, organization, environment, and tasks [35].

2.5. The General Design Literature Discussion

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" removes obstacles that exist in the environment for people with disabilities. In the 1970s, Europe and the United States adopted "accessible design" for the needs of people with reduced mobility in their living environment, but not for products. The concepts of universal design, inclusive design, and universal design are recognized, but none of them can meet the requirements of every possible user [36].

One American architect, Michael Bednar, argues that after removing the barriers in the environment, everyone's faculty can be improved and it is necessary to establish a new and broader concept that goes beyond a broad design, that is, the term extensive design. It is not possible to fully explain their philosophy. The purpose of universal design is to promote the interaction between the product and the environment and allow the user to use the product effectively without having to adjust the product [37]. Universal design is a worldwide movement that engages the widest range of users with the environment, products, and communication. The trend of "normalization" and "returning to the mainstream" has caused "accessibility" to be an important part of the issue of physical and mental obstacles and "general design" has been further promoted [38]. Universal design is a design philosophy that aims to create an inclusive and sustainable society where everyone can participate as much as possible [39,40]. In addition, the Universal Design Learning (UDL) framework increasingly attracts the attention of researchers and educators as an effective solution to bridge the gap between learner and individual differences.

The European design and fashion market has been well developed and design and textile products have been protected since very early on, mainly through the German design method [41]. The so-called German systematic design approach actually evolved from the second half of the last century and related design guidelines have been proposed and updated until 2021 [42–44]. Nevertheless, the model proposed by G. Pahl and W. Beitz still represents one of the most recognized versions of the recall approach, which consists of four key phases, namely, explicit design task, conceptual design, implementation design, and detailed design [45].

2.6. IPA

Importance-Performance Analysis (IPA) was proposed by Martilla and James (1977), in which they designed a SERVQUAL scale with five dimensions (tangibility, reliability, responsiveness, assurance, empathy) [46]. The concept is a questionnaire structure with a two-dimensional matrix from the service quality items that consumers think are important and the actual satisfaction of the items; then, the two-dimensional graph is divided into four quadrants and then the attributes of the essential items are divided into a two-dimensional matrix. The importance and expressiveness are, respectively, marked in the relevant quadrant positions and then specific strategies for quality improvement are judged and proposed based on the meanings of the quadrants of each attribute item [47–49]. The IPA is one of the effective methods to study image positioning. It presents the relative position of the importance of each attribute and performance in the form of image analysis, which can be used as a guide for cultural institutions in management and marketing [50]. For example, Tseng scholars used the IPA-Kano model to classify and diagnose the service attributes of airports and proposed opportunity service improvement, which was verified by the case study of the Taoyuan International Airport (TPE) [51]. Therefore, this study designed a folding chair questionnaire, collected 125 pieces of data for analysis, and obtained the practicality and verification of the research product.

3. Design Research

According to the aforementioned objectives and literature, the innovative design of the rapid assembly and deployment function of the folding chair is studied. In order to achieve the aforementioned objectives, innovative design research is carried out through the types of folding chairs, folding table, and chair design, repeated force damage, folding chair related patents, the TRIZ method toolset, human factors engineering, and general design. Additionally, an initial novelty assessment is conducted. As shown in Figure 1.

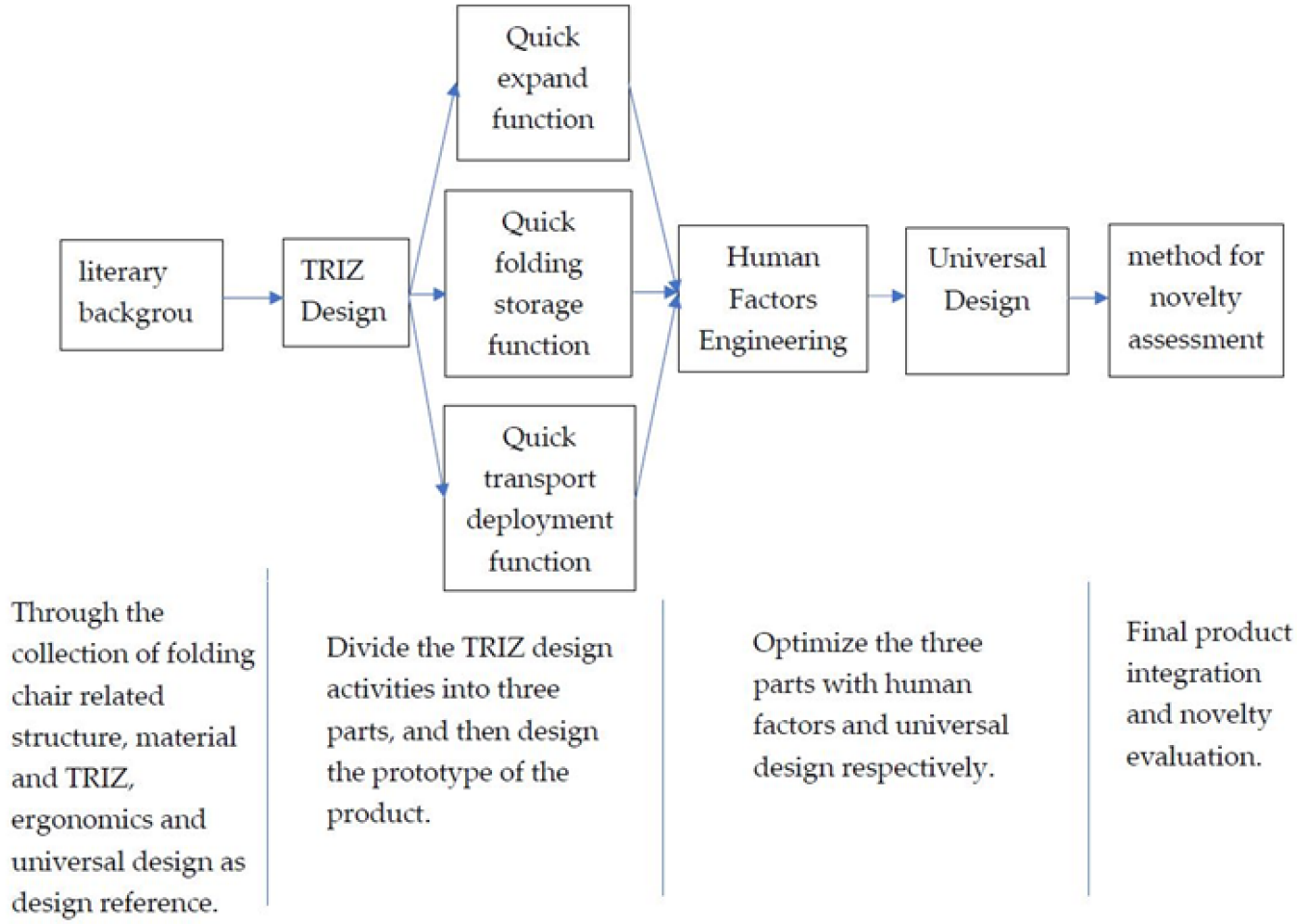

Figure 1. Design activity process.

3.1. Design Reference Goals for Folding Chairs

Before the development of TRIZ, the research product of this research will be researched and analyzed according to the relevant data found by the above-mentioned methods. In the end, we chose the operation method of opening and closing both hands of the folding chair with the backrest and without armrests as the reference target of this design activity and based on the length, width, and height of the unfolding and closing of the folding chair, as well as the dimensions of the back, seat, and legs as the reference target. The design reference is shown in Table 1.

Based on our choice of backrest and armless folding chairs for the problems created by each operating action and according to our goals to develop innovative design solutions. As shown in Table 2.

Table 1. Design reference goals for folding chairs.

Types of folding chairs	Folding chair with backrest and armrests. 	Armless folding chair with backrest. 	Armless folding chair without backrest. 
Operation method.	Four feet to the center.	Open and close both hands.	The storage method of the four feet folded to the center.
Advantage.	1. The rear is designed with a storage net. 2. Easy to carry. 3. Suitable for camping or outdoor use.	1. Can be folded into a flat surface for easy storage. 2. Lightweight and quick to operate. 3. Suitable for placing in large quantities in various occasions.	1. Small storage volume, easy to carry. 2. Suitable for camping or outdoor use.

Table 2. A potential list of traditional folding chairs.

Action	Question	Innovative Design Goals
Open	Generally, folding chairs cannot be unfolded quickly, and the safety of folding will also cause the possibility of pinching.	The TRIZ method is introduced into the innovative design of the folding chair for rapid unfolding.
Opening and closing	At present, most of the folding methods of folding chairs require bending over and merging with both hands to achieve the folding function of the folding chair. When arranging multiple chairs, it is possible to cause repetitive stress injuries and cause minor injuries to the waist and hands.	TRIZ introduces the innovative design of folding chairs for quick folding.
Storage action	At present, the general folding chairs are usually transported and arranged in the exhibition. Most of them require one chair or two chairs at a time. It is impossible to transport multiple chairs to the arrangement location. During the arrangement process, the chairs must be aligned one by one, which will require a lot of time and effort during the installation and process.	TRIZ introduces the innovative design of fast handling and exhibition arrangement functions.

3.2. Exploring the Innovative Design of the Folding Chair

In response to the innovative design of the fast-expanding folding chair, the TRIZ method is used to explore the design concept of the folding chair, and the human-engineered engineering method is used to analyze the operation mode. Finally, the universal design method is adopted to ensure the folding chair operation mode is more convenient and safer. The content is as follows.

3.2.1. The TRIZ Method Is Introduced into the Innovative Design of the Folding Chair for Rapid Unfolding

General folding chairs cannot be quickly unfolded and there is a possibility of pinching in the safety of folding. When the folding chairs are arranged in the exhibition, folding

will be caused in the operation method. The arrangement of chairs causes repetitive injuries and it takes a lot of time and labor to set up the latter. In order to solve the above problems, this study aimed to identify the 39 parameters of the technical contradiction matrix in the innovative design chair TRIZ method for the folding chair. The parameter to be improved is No.09 (speed), No.25 (time loss), No. 33 (easy to operate), No. 35 (adaptive), to avoid deterioration parameters No. 2 (fixed piece weight), No. 10 (strength), and No. 27 (reliability). Use the above-mentioned parameters to improve the parameters and avoid deterioration parameters to draw the contradiction matrix table, as shown in Table 3.

Table 3. Technical contradiction matrix for the rapid deployment of folding chairs.

Avoid Deterioration Parameters **Want to Improve the Parameters**	**2. Fixing Weight**	**10. Strength**	**27. Reliability**
9. Speed		13.28 15.12	11.35 27.28
25. Time loss	10.25 26.05	10.37 35.05	10.30 4
33. Easy to operate	06.13 1.25	28.13 35	17.27 8.40
35. Adaptability	19.15 29.16	15.17 20	35.13 8.24

In the invention principle corresponding to the summary technical contradiction matrix, the number of occurrences is as follows: No. 13 (reverse operation principle) and No. 35 (physical and chemical state transformation) are four times; No. 10 (pre-Principles of Operation, No. 15 (dynamic principle), and No. 28 (generation system) are all three times; and No. 5 (combination principle), No. 8 (balance principle), No. 17 (conversion to degree Principle), No.25 (self-help principle), and No.27 (abandonment principle) are two times.

In order to solve the problem of the innovative design of folding chairs, after exploring the TRIZ method, several inventive principles were selected, as shown in Table 4. Discovery No. 8 (balance principle): When designed to fold open, there is enough balance not to fold. The chair unfolds and collapses. This design activity is based on the principle of invention, corresponding to the technical contradiction matrix, and discussed separately through the literature and design structure.

Table 4. Explanation of the invention principles of quickly expanding and selecting folding chairs.

Selected Invention Principles	**Definition**
No. 8 Balance Principle	Combine in a way that strikes a balance.
No. 10 Pre-action Principle	"Prepare in advance" for what will happen later.
No. 13 Reverse Operation Principle	"Invert" the various elements.
No. 15 Dynamic Principle	That is deformation. In addition to adding movable parts and additional adjustment functions, static functions are selected according to the field.
No. 25 Self-help Principle	It means "do it yourself" and its idealization is that all actions can be customized.
No. 35 Physical and chemical state change	Try to replace the existing material and reaction state with other parameters.

No. 10 (pre-action principle): Install a cushion sponge under the legs of the chair, so that the folding chair generates a reaction force and the sound becomes fainter to achieve the pre-action principle. According to the experimental data of Research on the Characteristics of Buffer Material Used as Hip Protector, the soft buffer material is effective for relatively small transient impacts, but when the impact becomes larger, the buffering effect will be reduced, that is, the absorption of the impact becomes poor. In contrast, hard cushioning

materials have a good absorption capacity for large transient shocks. However, if the hardness is too high, the deformation of the material becomes smaller, which leads to poor absorption [52]. Using the data inside as the reference for the sponge cushioning is shown in Figure 2. No. 13 (reverse operation principle): The operation of the user pull ring at the back of the folding chair differs from typical folding chairs in realizing the reverse operation principle, as shown in Figures 3 and 4. No. 15 (dynamic principle): The legs, seat, and frame of the folding chair can be un-folded by using the shaft connection to realize the dynamic principle, as shown in Figure 5. No. 25 (self-help principle): The user pulls the ring on the folding chair backrest. When the chair leg is opened, it will connect with the magnet of the seat cushion and the weight of the chair leg will naturally expand downward to achieve the self-help principle, as shown in Figure 6. No. 35 (physical and chemical state change): changes the weight and center of gravity of the chair leg so that the leg is naturally extended, as shown in Figure 7.

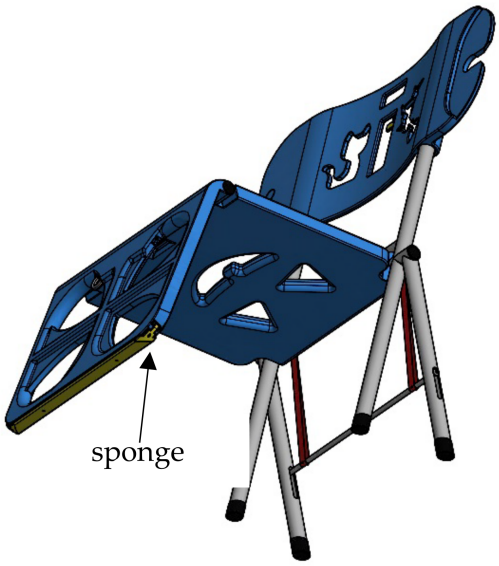

Figure 2. Diagram of the sponge location.

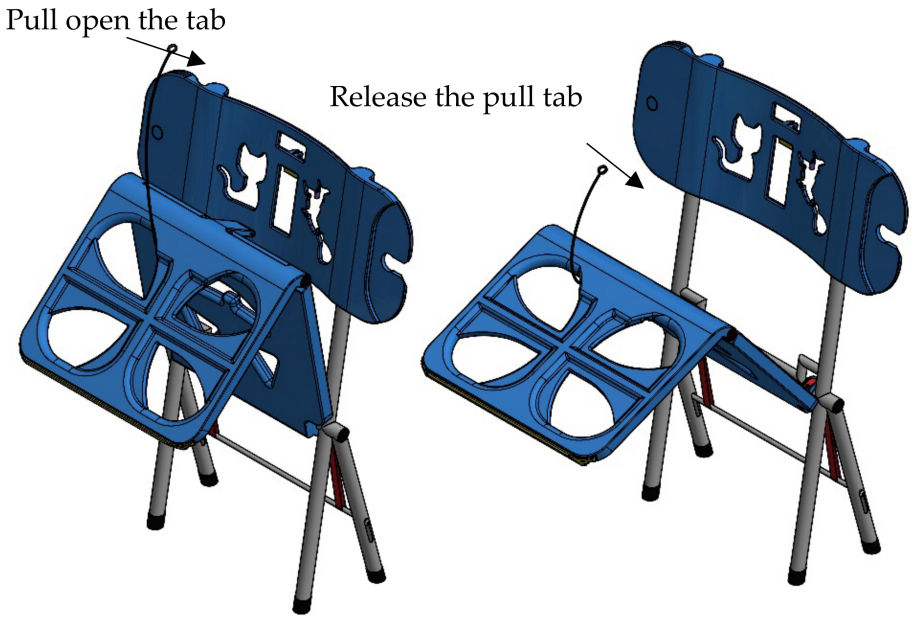

Figure 3. Diagram illustrating the pull tab operation.

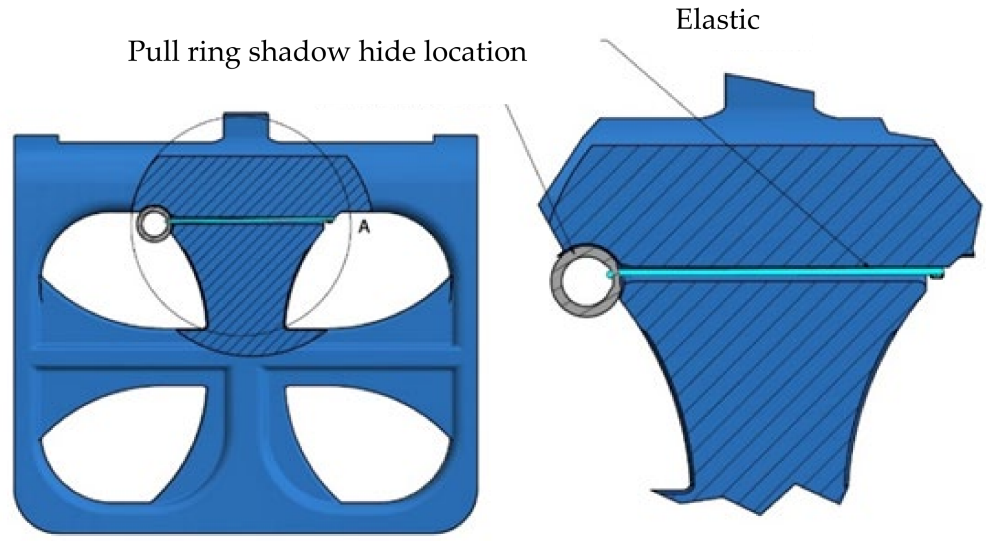

Figure 4. Diagram of the pull ring placement.

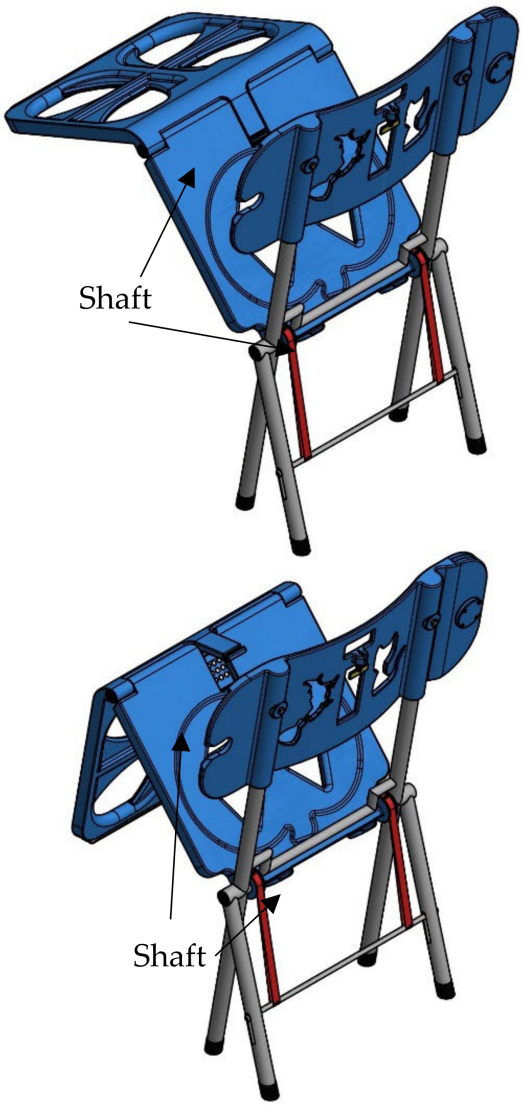

Figure 5. Diagram of the shaft locations.

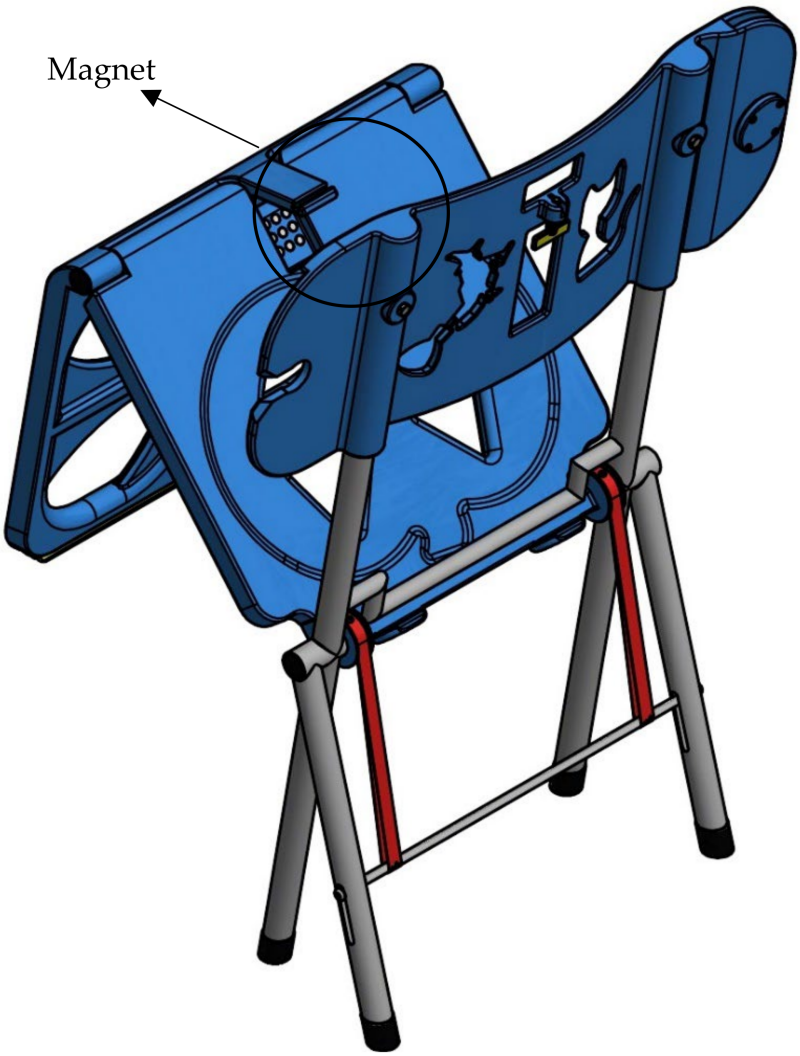

Figure 6. Diagram of the magnet location.

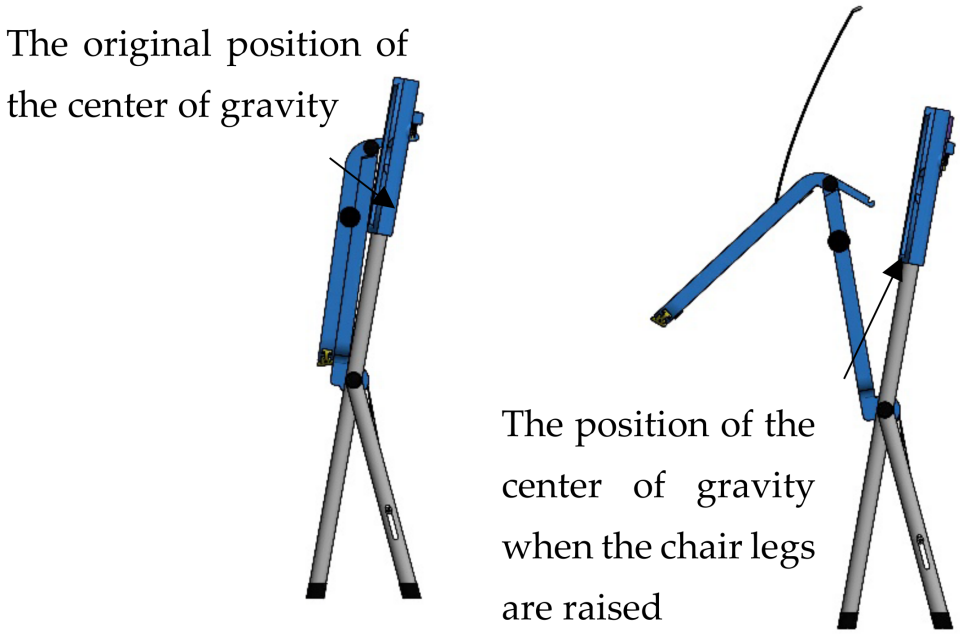

Figure 7. Diagram of the change in the center of gravity.

3.2.2. Innovative Design for the Rapid Development of Human-Introduced Folding Chairs

At present, most of the folding chair deployment methods need to be bent over and pulled apart by both hands to achieve the folding chair deployment function. When arranging a plurality of chairs, it may cause repeated damage to the waist and the hand and there is a risk of pinching in a folding chair operation, which is time consuming for the arrangement time. In order to improve this problem, this study is aimed at the current operation mode and deployment speed of folding chairs, using man-machine system analysis of human factors engineering design, in order to solve the micro-injury of repeated actions, the danger of operation, and the time-consuming problem of analysis. When the folding chair is operated, the minimal impact on the body and the general folding chair structure design are obtained along with three design methods.

1. Repeated action micro-injury: For repetitive movements, it is found that the operation of the general folding chair needs to simplify the extra action to reduce the movement of excessive parts of the body. In this study, the innovative design operation of the folding chair is quickly expanded into a folding chair. One hand at the back is used to operate the folding chair to remove the repetitive movement of the waist and reduce the repeated movement of the hand.
2. Hazard of operation: When a large number of folding chairs are arranged in a large number, it may be dangerous to handle the hand and flash to the waist for the sake of speed. In this study, the innovative design of the folding chair is rapidly developed, in order to solve the above problems, with one hand, the chair foot and the seat cushion are attached to the natural gravity downwards, so that the hand does not touch the folding range of the folding chair, thereby improving the safety of the folding chair. See Figure 8.

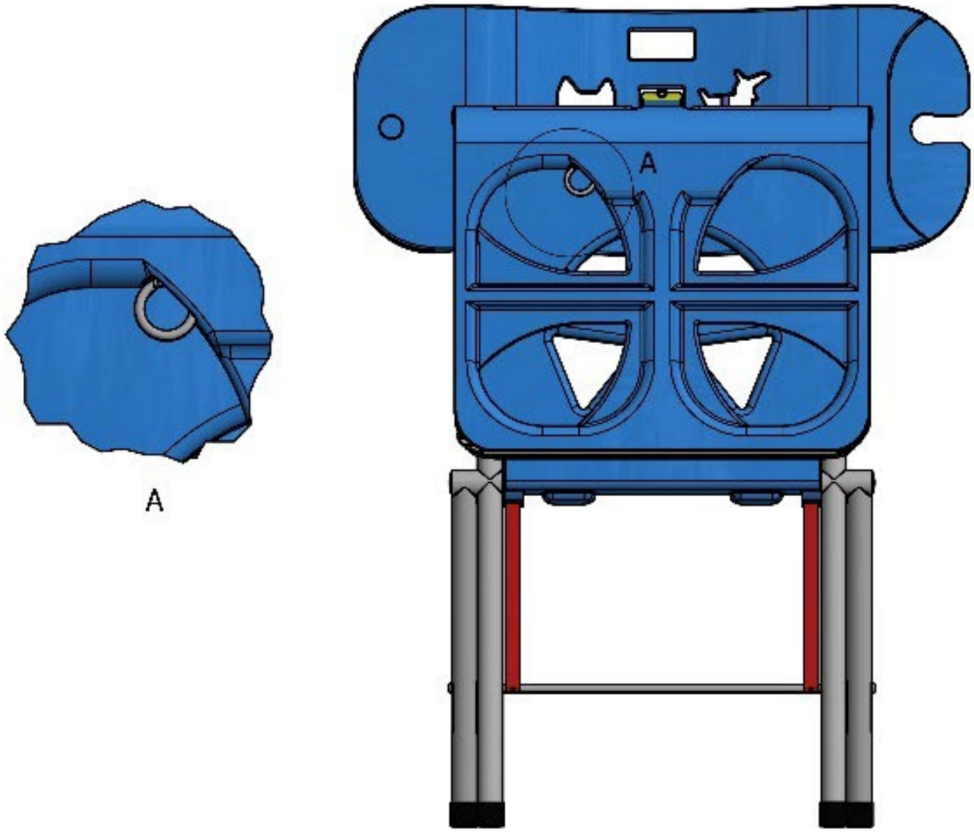

Figure 8. Diagram of the pull ring location.

3. Arrange time-consuming problems: Generally, when the folding chair is opened, it needs to be bent over and pulled out to achieve the function of unfolding the folding chair, but the opening time is not simplified. This study is designed to open the chair and the chair cushion with one hand. The fitting is naturally carried out by gravity and the movement can be quickly developed to enhance the convenience of the folding chair. See Figure 9.

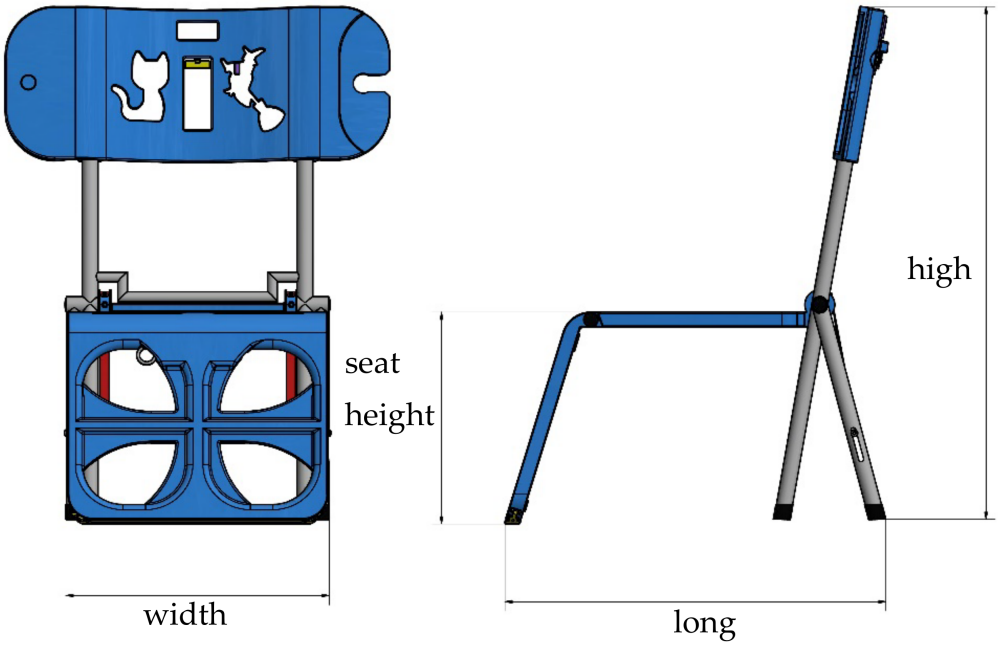

Figure 9. Diagram of the folding chair's size.

3.2.3. The Universal Design Method Introduces the Innovative Design of the Folding Chair

In the innovative design of the folding chair, it is designed to use a pull ring to pull the chair foot up and let the chair foot and the seat cushion naturally descend downwards by gravity to achieve the speed expansion function, using the TRIZ method 39. The engineering parameters and forty principles of invention are used as the reference basis for the design. Finally, the fair use and simple and intuitive use of the universal design method, labor saving, and the innovative design of the quick handling and deployment functions are addressed when used in size and space for improvement.

1. Fair use: Using the principle of fair use of the seven principles of universal design, use one hand to pull the chair foot with a pull ring and let the chair foot and the seat cushion expand naturally under gravity to achieve speed development. Functionally, the size of the pull ring is suitable for various users and the position of the pull ring is designed to be the height that the user can use when standing backwards. The innovative design of the folding chair is in accordance with the fair use principle.
2. Simple and intuitive use: Using the simple and intuitive use principle of the seven principles of universal design, the design position of the pull ring is modified into an asymmetrical position, so that the user can clearly see the position of the pull ring and quickly operate the folding chair quickly. The innovative design that allows the folding chair to expand quickly is simple and intuitive.
3. Labor-saving: Using the labor-saving principle of the seven principles of universal design, improving the material of the chair foot and designing the shape of the hole to reduce the weight of the chair foot, allowing the user to open the folding chair more flexibly and quickly, so that the folding chair can be quickly deployed. Innovative design meets the principle of labor saving.

4. When using size and space: In the seven principles of universal design are the principles of size and space, improving the distance and size after unfolding, ensuring the use of space during the exhibition are more convenient, and ensuring the folding chair is an innovative design. Compliance is the principle of size and space usage.

3.3. Exploring the Innovative Design of Folding Chairs for Quick Folding

For the innovative design of the fast-folding folding chair, the TRIZ method is used to improve the design of the folding chair and then the human-engineered engineering method is used to analyze the operation mode. Finally, the universal design method is adopted to ensure the folding chair operation mode is more convenient and safer. The content is as follows.

3.3.1. Innovative Design of TRIZ-Imported Folding Chair for Quick Folding

Currently, most of the folding methods of folding chairs need to bend over and combine with both hands to achieve the folding function. When arranging multiple chairs, it may cause repeated force injury and cause slight injury to the waist and hands. Generally, there is no standing function after folding and it is also time-consuming for the arrangement time. In order to solve the above problem, this study investigates the folding chairs through the fast-folding of the innovative design chair TRIZ method of the technical contradiction matrix of thirty-nine items of engineering parameters to find improved parameters including No. 02 (fixed piece weight), No. 09 (speed), No. 25 (time loss), No. 33 (Easy to operate), to avoid deterioration parameters are No. 10 (force), No. 27 (reliability), and No. 35 (adaptive). The above-mentioned parameters are used to improve the chair and avoid deterioration parameters to draw contradictions. This is seen in the array table, as shown in Table 5.

Table 5. Folding chair fast-folding technology contradiction.

Avoid Deterioration Parameters Want to Improve the Parameters	**10. Strength**	**27. Reliability**	**35. Adaptability**
2. Fixing weight	8.10 19.35	10.28 8.03	19.15 29
9. Speed	13.28 15.19	11.35 27.28	15.10 26
25. Time loss	10.37 35.05	10.30 4	35 28
33. Easy to operate	28.13 35	17.27 8.40	15.34 1.16

In the invention principle corresponding to the summary technical contradiction matrix, the number of occurrences for No. 10 (pre-action principle), No. 28 (generation mechanical system), and No. 35 (physical and chemical state transformation) are five times; No. 15 (dynamic principle) is 4 times; No. 8 (balance principle) and No. 19 (periodic principle) are three times; and No. 13 (reverse operation principle) is 2 times.

In order to solve the problem of the innovative design of folding chairs, after exploring the TRIZ method, several inventive principles were selected, as shown in Table 6. Discovery No.8 (balance principle): designed to fold the chair and increase the support feet, so that when folding and when it is closed, there is enough balance to prevent the folding chair from collapsing. No. 10 (pre-action principle): The cushioning sponge is arranged at the rear of the chair and the seat cushion, so that the folding chair can reduce the reaction force and the sound to achieve the pre-action principle. This is based on the data from the Research on the Characteristics of Buffer Material Used as Hip Protector for the design reference, as shown in Figure 10. No. 13 (reverse operation principle): The operation mode of the pedaling lever is used by the person behind the folding chair and the folding posture

of the general folding chair is different to achieve the reverse operation principle. See Figure 11. No. 15 (dynamic principle): Design the spring fasteners so that when the folding chair is folded, the spring rises quickly and fastens to achieve the dynamism principle, as shown in Figure 12. No. 35 (physical and chemical state change): Change the weight of the chair legs to cause the collection to be more laborsaving.

Table 6. Explanation of the principle of selection and invention of folding chairs for quick folding.

Selected Invention Principles	Definition
No. 8 Balance Principle	Combine in a way that strikes a balance.
No. 10 Pre-action Principle	"Prepare in advance" for what will happen later.
No. 13 Reverse Operation Principle	"Invert" the various elements.
No. 15 Dynamic Principle	That is deformation. In addition to adding movable parts and additional adjustment functions, static functions are selected according to the field.
No. 35 Physical and chemical state change	Try to replace the existing material and reaction state with other parameters.

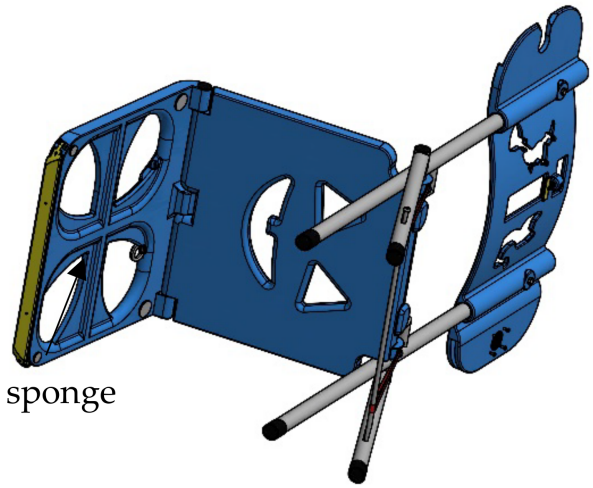

Figure 10. Diagram of sponge placement.

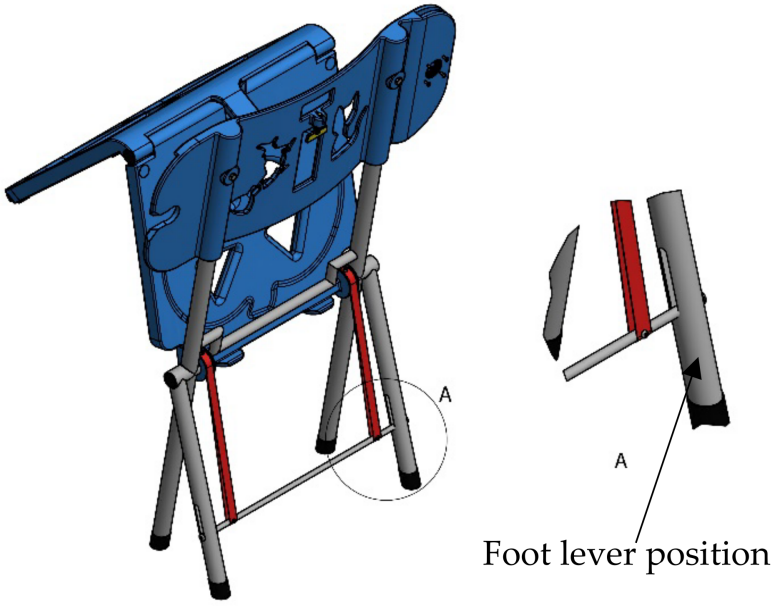

Figure 11. Diagram of the foot lever position.

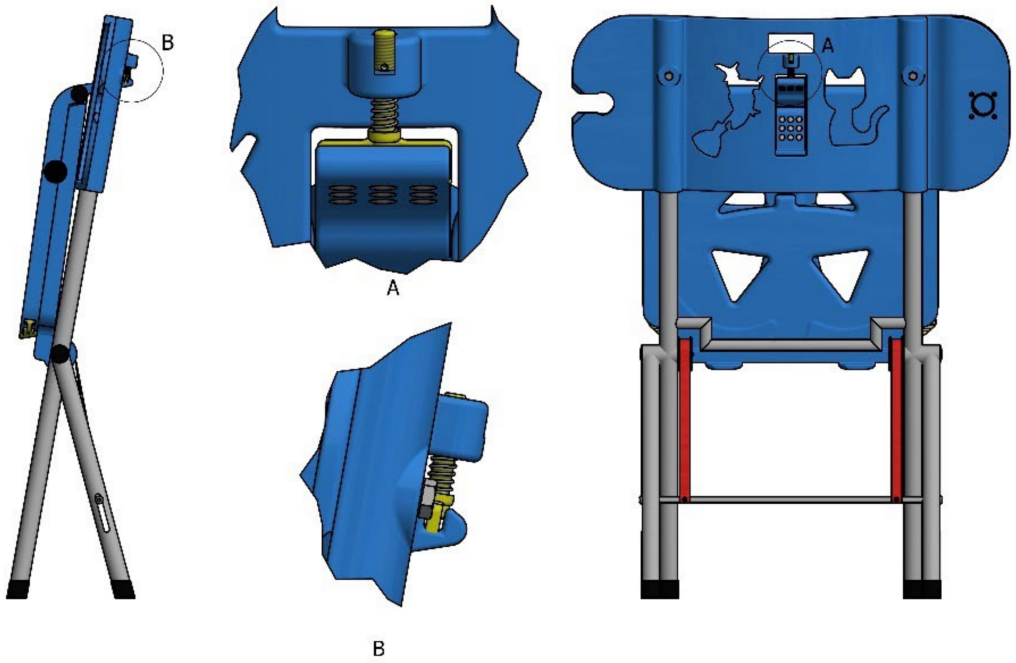

Figure 12. Diagram of the spring fasteners position.

3.3.2. Innovative Design of Human Body Due to the Introduction of Folding Chairs for Rapid Folding

At present, most of the folding chairs are folded in both hands to achieve the folding chair folding function. When arranging multiple chairs, it may cause repeated damage to the waist and the hand to cause slight damage. Generally, the folding function does not stand after folding and it is time consuming for the arrangement time. In order to improve this problem, this study is aimed at the current operation mode of the folding chair and the folding and standing. The human–machine system analysis based on human factor engineering is used to solve the micro-injury of repeated actions, the standing problem after folding, and the time-consuming problem. The user's minimal impact on the body when operating the folding chair and the general folding chair structure design are analyzed and three design methods are drawn.

1. Repeated action micro-injury: For repetitive movements, it is found that the operation of the general folding chair needs to simplify the extra action to reduce the movement of excessive parts of the body. In this study, the innovative design operation action of the folding chair is quickly folded into a person standing in the fold. Use the foot to step on the back of the chair to operate the folding chair to remove the re-action of the waist and the hand, causing the folding chair to be safer.
2. Standing problem after folding: Generally, the folding chair cannot stand when the folding is folded, causing the chair to fall to the ground. In the case of a large number of folding, most of the time is saved on the ground to save the time, causing the damage rate of the chair to increase. Taking it away can cause damage to the body and waste time. To solve the above problems, the bicycle is designed to be operated by using a foot pedal to operate the folding chair and a supporting foot is added to the rear leg. When the chair is folded, the chair can stand on its own.
3. Arrange time-consuming problems: When the chair is arranged in the exhibition, the exhibitors will need to quickly fold the folding chair when the exhibition is closed. The folding operation of the folding chair needs to be bent and folded, so that the folding chair operation is not streamlined when the arrangement is large. This study was designed to use the man to step on the pedal after the folding chair to achieve a quick folding.

3.3.3. Universal Design Introduces the Innovative Design of Folding Chair for Quick'Folding

In the innovative design of the folding chair, the design of the single-foot operation uses the pedal under the back of the chair and the pedal is stepped on to fold the seat up, so that the legs are naturally folded down and buckled back to the back of the chair. Fasteners are used to achieve the fast-folding function. The 39 engineering parameters of the TRIZ method and the forty invention principles are used as the basis for the reference. Finally, the fair use and simple and intuitive use of the universal design method, labor saving, and size and space are used to improve the innovative design of the quick handling and deployment functions.

1. Fair use: Using the principle of fair use of the seven principles of universal design, the folding chair can be used to fold the back of the folding chair and the position of the pedal can be improved, so that the sole of the foot can be gently tilted and stepped on, so that the folding chair can be easily folded. A variety of operators can easily fold, so that the innovative design of the folding chair can be quickly developed in accordance with the principle of fair use.
2. Simple and intuitive use: Using the simple and intuitive principle of the seven principles of universal design, the tread bar is placed behind the folding chair, and the connecting line is fastened to the seat cushion so that the operator can clearly see that the folding chair is rapidly expanding from behind the folding chair. The innovative design and operation, combined with the simplicity of operation, cause the folding chair's innovative design to be fast and easy to use. See Figure 13.

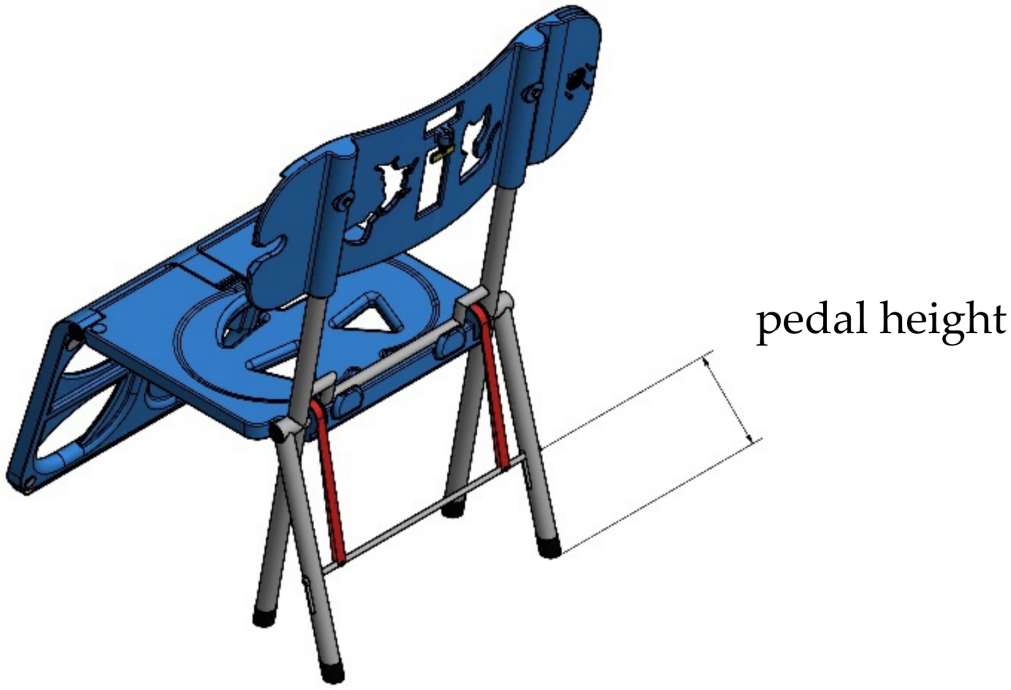

Figure 13. Diagram of the pedal height.

3. Labor-saving: Using the labor-saving principle of the seven principles of universal design, the chair cushion, and the chair foot material are changed to lighter materials and the holes and shapes are designed to reduce the weight of the folding chair, so that the user can operate the folding chair to be more labor-saving. The innovative design that allows the folding chair to unfold quickly is in line with the principle of labor saving. See Figure 14.

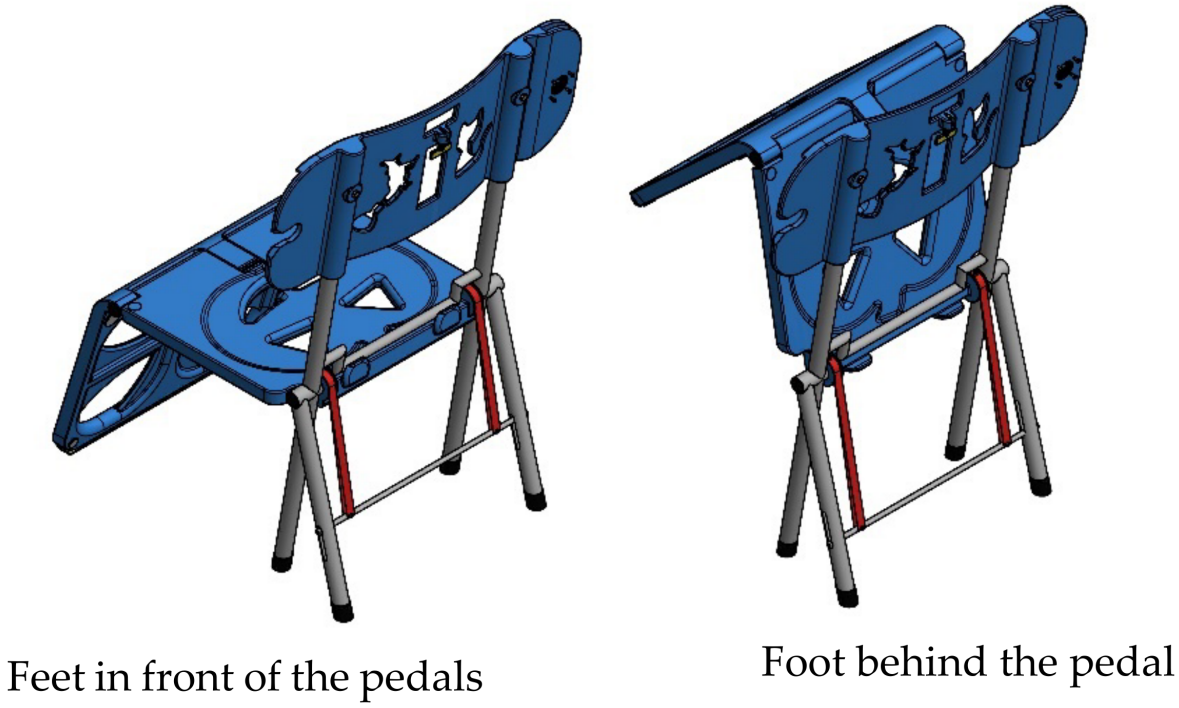

Figure 14. Diagram of feet in front of and behind the pedals.

4. When using size and space: The seven principles of universal design involve the principles of size and space. The folding thickness after folding is improved and the folding chair can be folded and placed in the room for more use. The fast expanding innovative design meets the principles of size and space, as shown in Figure 9.

3.4. Innovative Design of the Rapid Handling and Deployment of Folding Chairs

Innovative design for the rapid handling and deployment of folding chairs, analysis of the operation mode by the human factors engineering method, the TRIZ method to improve the folding chair design, and the most common use of the general design method are combined to cause the folding chair operation arrangement to be performed more quickly; the content is as follows.

3.4.1. TRIZ Introduces Innovative Design for Rapid Handling and Deployment

Most of them need one chair at a time or two chairs at a time. It is impossible to transport multiple sheets to the arrangement location. During the arrangement process, the chairs must be aligned one by one. It will cost a lot of effort and time during the installation and process. This study is aimed at the thirty-nine engineering parameters of the technical contradiction matrix in the TRIZ method of the innovative design chair of the folding chair for rapid handling. The parameters to be improved are No. 02 (fixed piece weight), No. 12 (shape), No. 27 (reliability), and No. 33 (easy to operate) and the deterioration parameters are No. 09 (speed), No. 25 (time loss), and No. 35 (adaptive). This will improve the parameters and avoid deterioration parameters to draw contradictory matrix tables, as shown in Table 7.

In the invention principle corresponding to the summary technical contradiction matrix, the number of occurrences is five or less and for No. 10 (pre-action principle), No. 15 (dynamic principle), and No. 35 (physical and chemical state change) are four times; and No. 1 (segmentation principle), No. 4 (asymmetry principle), No. 13 (reverse operation principle), No. 18 (vibration principle), No. 28 (generation mechanical system), and No. 29 (pneumatic or hydraulic) are two times.

Table 7. Technical contradiction between the rapid movement of folding chairs.

Avoid Deterioration Parameters Want to Improve the Parameters	**9. Speed**	**25. Time Loss**	**35. Adaptability**
2. Fixing weight		10.20 35.26	19.15 29
12. Shape	35.15 34.18	14.10 34.17	1.15 29
27. Reliability	25.35 11.28	10.30 4	13.35 8.24
33. Easy to operate	18.13 34	4.28 10.34	15.34 1.16

In order to solve the problem of innovative design of folding chairs, after exploring the TRIZ method, several inventive principles were selected, as shown in Table 8. Discovery No. 1 (segmentation principle): the two sides are divided into the joint and the joint head to ensure the seat back is able to connect quickly, as seen in Figure 15. No. 10 (pre-action principle): design the guide rail with the joint to ensure the seat back and the back of the chair can quickly engage to achieve the pre-action principle, as seen Figure 16. No. 13 (reverse operation principle): by using the connection between the seat back and the seat back, multiple folding chairs can be simultaneously transported and aligned to achieve the reverse operation principle, as seen in Figure 17. No. 15 (dynamic principle): Design the joint spring fastener. When the seat back is engaged, the spring is automatically fastened to achieve the dynamization principle. See Figure 18. No. 35 (physical and chemical state change): change the size of the seat back so that the distance between the folding chair and the folding chair comes out directly, without having to adjust the distance between the chair and the chair one by one. See Figure 19.

3.4.2. Innovative Design for Introducing Rapid Handling and Deployment Functions for Human Engineering Design

At present, the general folding chairs are arranged in the transportation and exhibition. Most of them need one chair or two chairs at a time. It is not possible to carry them to the arrangement place. The chairs must be aligned one by one during the arrangement process. It will require a lot of effort and time in the exhibition and process. In order to improve this problem, in view of the layout and handling process of the current folding chair, the human–machine system analysis based on human engineering design was used to solve the problem of not being able to carry more transportation problems, deployment and exhibition time, and two design methods were obtained.

1. It is impossible to carry more problems: The folding chair cannot be transported more than one time and it needs to be transported back and forth many times, which wastes time and labor costs. In this study, the innovative design of the folding chair quick handling and deployment function uses the folding chair to extend back. The folding chair is joined to the back of the folding chair so that two people can carry from five to eight chairs at the same time, so that the folding chair can be quickly transported.
2. Time-consuming problems in deployment: Generally, the folding chairs need to be aligned one by one during the exhibition. The deployment process is very time-consuming and cannot be quickly deployed. The innovative design of the folding chair for rapid handling and deployment functions uses the folding chair to extend back and fold. The chair is engaged with the back of the folding chair so that the jointed chairs are aligned and transported directly to the positioning without any alignment.

Table 8. Explanation of the principle of selection and invention of folding chairs for quick transport.

Selected Invention Principles	Definition
No. 1 Segmentation Principle	A principle that relies on segmentation to solve problems.
No. 10 Pre-action Principle	"Prepare in advance" for what will happen later.
No. 13 Reverse Operation Principle	"Invert" the various elements.
No. 15 Dynamic Principle	That is deformation. In addition to adding movable parts and additional adjustment functions, static functions are selected according to the field.
No. 35 Physical and chemical state change	Try to replace the existing material and reaction state with other parameters.

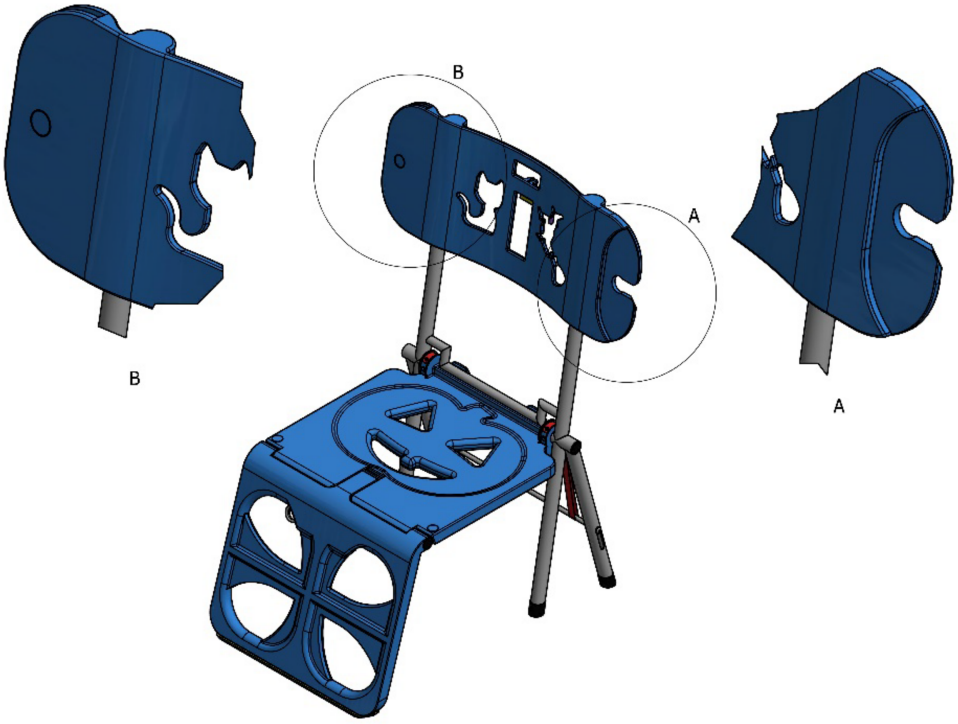

Figure 15. Diagram showing the connection between the seat back and backrest.

Figure 16. Diagram showing the connection between the two seat backrests.

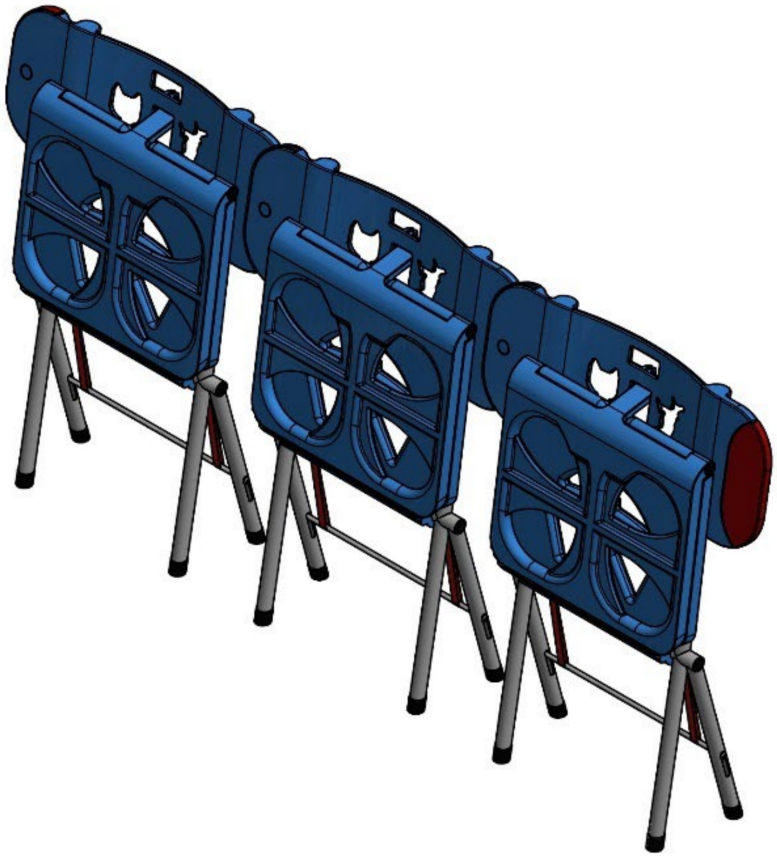

Figure 17. Diagram showing the automatic fastening of the joint spring fastener.

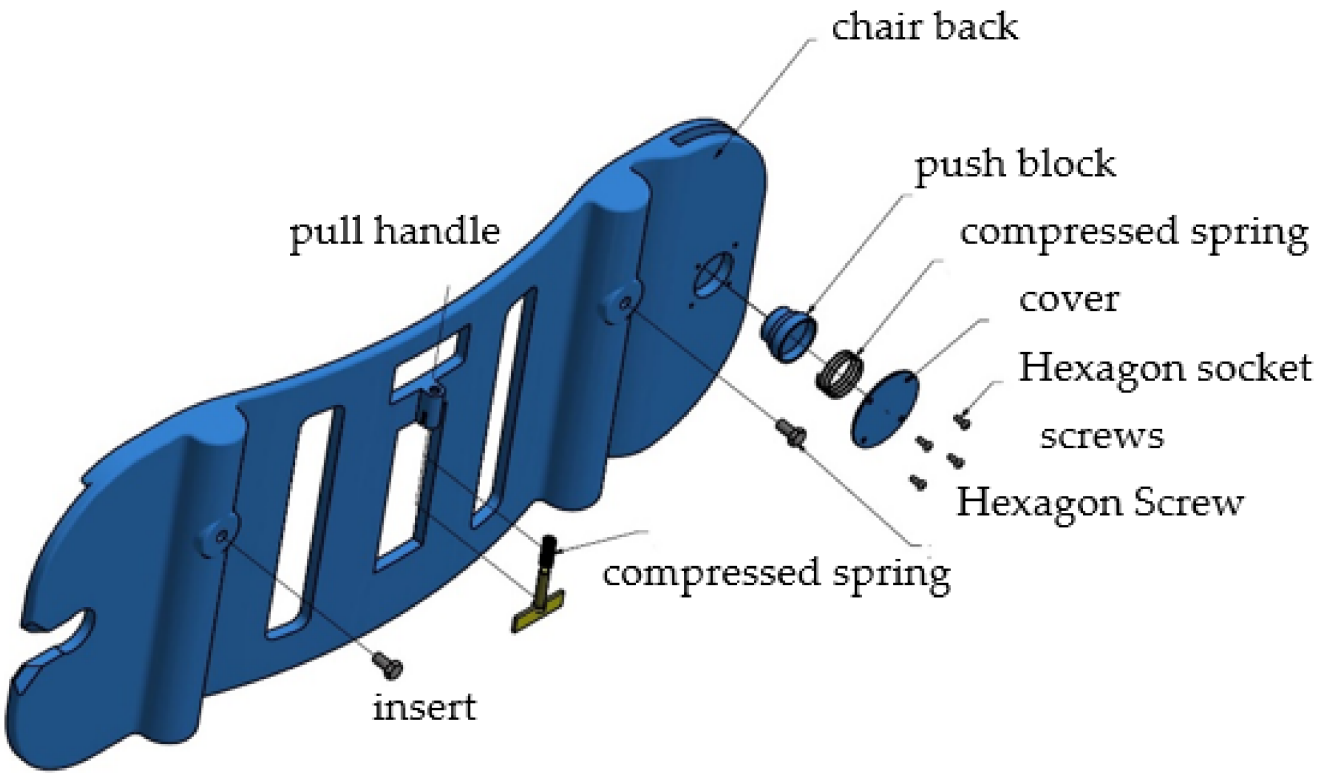

Figure 18. Diagram of the back of the folding chair in an expanded view.

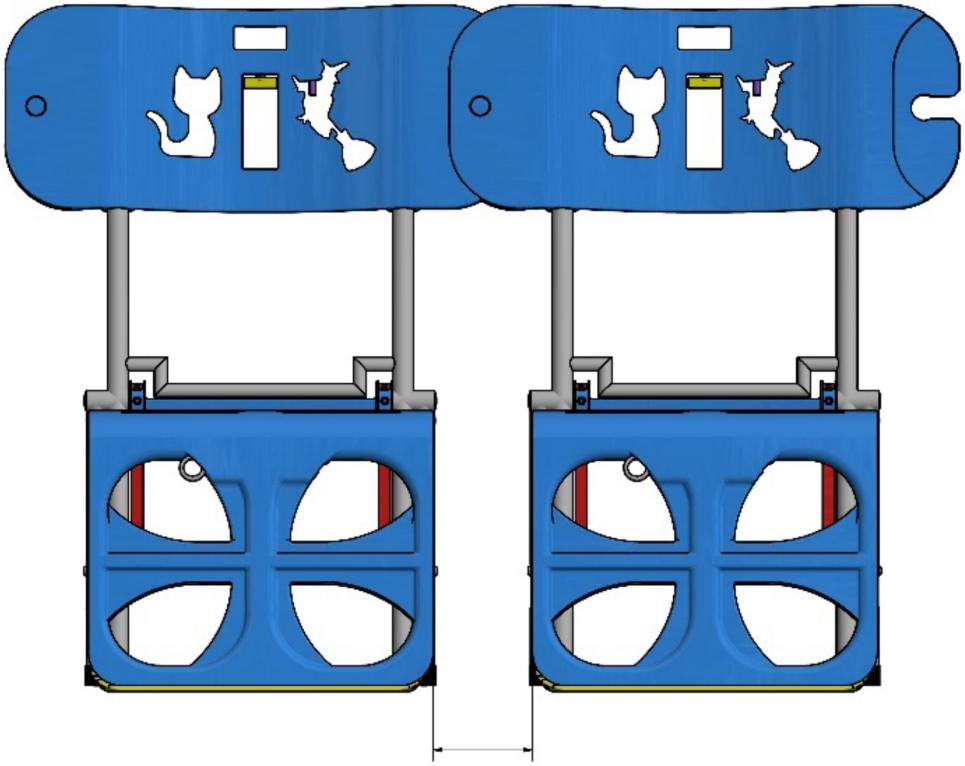

Figure 19. Diagram showing the distance between the two folding chairs.

3.4.3. Universal Design Introduces Innovative Design for Rapid Handling and Deployment

For the innovative design of rapid handling and deployment functions, the chairs are designed as a connection of stacking chairs and backs to achieve fast handling and rapid deployment, using the 39 engineering parameters of the TRIZ method and forty principles of invention as the basis for reference. Finally, the universal design method is fair use, simple and intuitive use, labor saving, and is an improvement of the innovative design of the quick handling and deployment function when size and space are used.

1. Fair use: Using the fair use principle of the seven principles of universal design, the folding is increased by the buckle of the seat back, so that the back and the back of the chair can be automatically aligned and fastened by the inclination without careful alignment. The mouth is suitable for a variety of operators to operate, so that the innovative design of the rapid handling and deployment functions is in line with the principle of fair use. See Figure 18.
2. Simple and intuitive use: Using the simple and intuitive principle of the seven principles of universal design, the shape of the joint extending from the back of the chair is designed to have a hole on the side of the interface without a hole and the joint head is designed to have a hole so that the operator can immediately distinguish between the joint and the joint head, allowing the operator to use the innovative design of quick handling and deployment functions easily and intuitively. See Figure 15.
3. Labor-saving: Using the labor-saving principle of the seven principles of universal design, the fasteners that combine the back of the chair and the seat back are quickly fastened by the weak spring. The seat back can be separated from the back of the chair by gently pressing, so that the back of the chair is connected with separate operation points are more labor-saving.
4. When size and space are used: The joints and joint heads extending on both sides of the back of the chair are sized to match the distance between the chair and the chair, so that the innovative design using the quick handling and setting function is at the distance of the chair. See Figure 19.

3.5. Preliminary Novelty Assessment Method

Creativity is essential for designing products and enabling innovation. Assessing creativity can help identify innovative designers and products and support improvements in both. According to the definition of Sarkar and Chakrabarti (2008), the core components of creativity are "novelty" and "usefulness", so the direct measure of creativity should be the measure of product novelty and product usefulness [53]. This design activity uses the novelty assessment method proposed by Sarkar and Chakrabarti (2011) [54], as shown in Figure 20, and compares it with a general folding chair and a quick-deployment folding chair, as shown in Table 9.

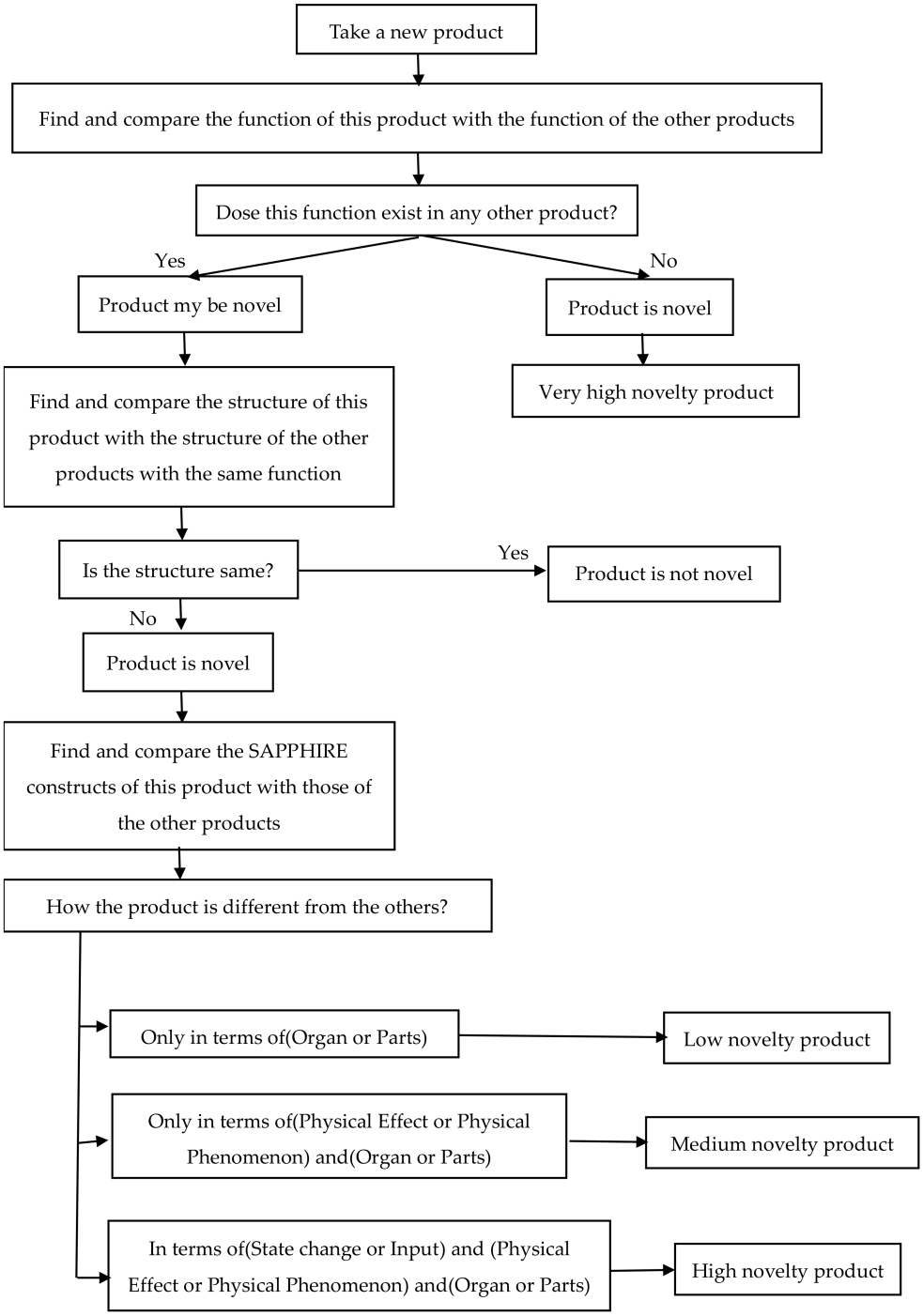

Figure 20. Steps of the method for assessing novelty.

Table 9. Comparison of general folding chair and a quick-deployment folding chair.

FBS	*SAPPhIRE*
For general folding chairs: Function: can be folded to reduce the space. Behavior: hands open so that the back and legs cross to form a chair and hands close to reduce the volume of storage. Structure: chair legs, back, seat.	Effect: foldable. State change: hands open so that the back of the chair and the legs cross to form a chair. Physical phenomenon: the use of the principle of cross triangular support. Organ: chair back, chair legs, chair seat. Input: open and close with the force of both hands.
For quick deployment of folding chairs. Function: can be folded to reduce the space, can be combined with multiple transport. Behavior: open with one hand so that the chair back and legs cross to form a chair, a single leg closed to reduce the volume of storage, a single chair can stand, multiple chairs can be combined and transported. Structure: back, legs, seat, pull ring, tread bar, fasteners, merging street.	Effect: foldable, can be combined with multiple sheets. State change: pull the pull ring to release the fastener to put down the chair legs and seat. Physical phenomenon: the principle of using four legs to support and the principle of merging multiple chairs. Organ: back, legs, seat, pull ring, pedal lever. Input: open with one hand and close with one foot.

Now, the novelty of the "Quick Display Folding Chair" is evaluated by asking the following questions.

1. "Does this feature exist in any other product?" The answer is "Yes". Therefore, the product is not a "very new" product, see Figure 20.
2. "Is the structure the same as other products?" The answer is no, i.e., the structure of the Quick Display Folding Chair is different from that of a normal folding chair. Therefore, the product has some novelty, see Figure 20.
3. Next, we compare the SAPPhIRE model of the Rapid Display Folding Chair with the general folding chair. It is found that the fast-folding chair in the physical phenomenon and the general folding chair have the principle of support, but the fast-folding chair also has the principle of merging multiple chairs. Additionally, the fast-folding chair state changes the way it opens and its organ adds a new pull ring and pedal lever. Therefore, the speed folding chair is a "high novelty" product, see Figure 20.

3.6. IPA

This research uses 22 items of five dimensions from the SERVQUAL scale, including 4 items of "tangibility", 4 items of "reliability", 4 items of "reactivity", 5 items of "assurance", and 5 items of "similarity". Semantic modification is used to form the questionnaire for this research; each item is distinguished by its importance and the actual feeling of the current situation, respectively, using a 5-point Likert Scale. Due to the impact of the epidemic, a Google form was used to issue questionnaires for online surveys; 154 questionnaires were recovered, 8 were invalid (including incomplete answers) and 146 were valid questionnaires, meaning the effective questionnaire recovery rate was 94.8%. There is little difference between men and women in the background information of the research subjects. The age group is mostly 40–50 years old (36%), the occupation is mainly public and business (48%), and the education level is mostly university (53%). The questionnaire analysis showed that the overall reliability of importance, satisfaction, and agreement was 0.977; the reliability of each other dimension was between 0.7 and 0.8. The results showed that the scale of this questionnaire had good consistency.

The quality importance and the overall average value of satisfaction obtained through the folding chair satisfaction questionnaire are 4.755 and 3.248, respectively, and the results are drawn into an IPA matrix, as shown in Figure 21.

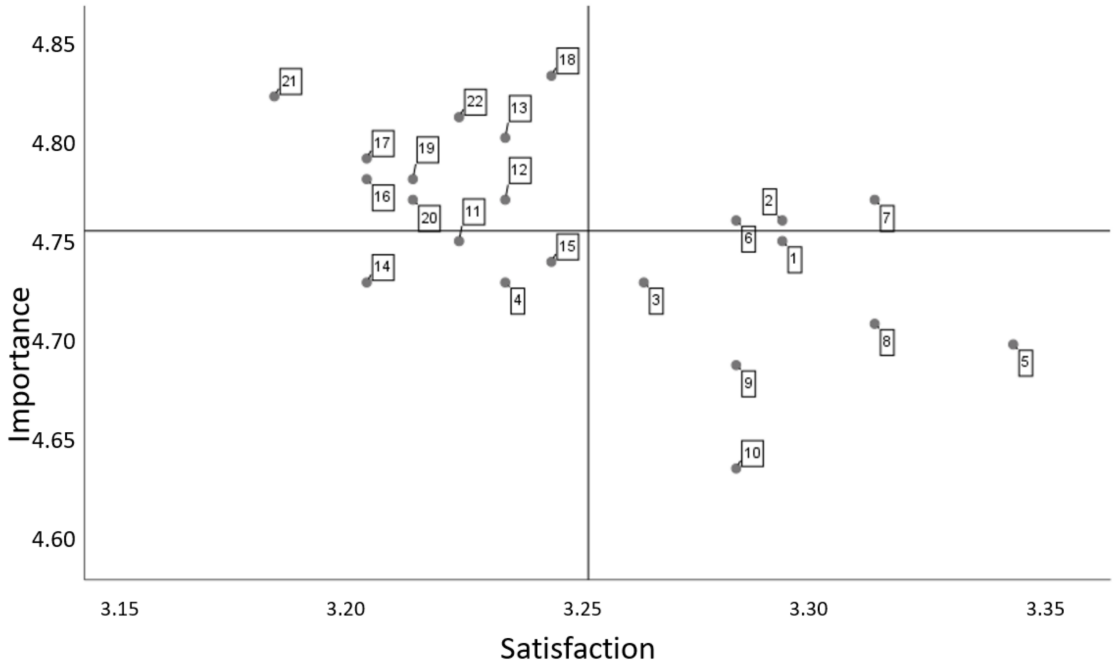

Figure 21. Folding chair satisfaction IPA matrix.

From the IPA analysis results in Figure 21, it can be seen that among the four quadrants identified by the IPA, there are three items that continue to remain in the "first quadrant", namely "2. The seat cushion surface is wide and suitable for public use", "6. When unfolding, cushions are attached to the legs to absorb the impact force of unfolding and increase the service life of unfolding", "7. The left and right fasteners on the back of the folding chair are unidirectionally fixed and combined, and the fastener switch needs to be pressed after fixing. It can only be separated, which can increase the stability of the folding chair after the combination." It means that it has reached the level expected by people and its service level should continue to be maintained. The result shows that people attach great importance to safety and stability.

There are six items that are located in the "Second Quadrant" over-emphasized area, namely "1. The back of the chair has a lumbar support that is comfortable and inclined, and the backrest is designed with ventilation holes to dissipate heat", "3. The legs of the chair are supported by five feet for a more stable ride", "5. The rear four legs of the chair are made of aluminum alloy, and the other parts are made of plastic steel to increase the stability of use", "8. There is a certain distance between the seat cushion and the back of the chair when folded to avoid pinching when folded. The cushioning cushion is attached to absorb the impact force of the closing and increase the service life of the closing", "9. The folding chair is unfolded by the offset of the center of gravity, so it will unfold naturally after being released. It can be quickly folded by stepping on it, and the opening and closing speed is fast", and "10. The back of the folding chair and the back of the chair can be directly combined after they are inserted. If they need to be separated, they need to press the button switch. The folding speed of the folding chair is fast". It turns out that people are very satisfied with the folding. However, the importance is not so great and resources can be moved to the third and fourth quadrants for greater benefits.

There are four items located in the secondary improvement area of the "third quadrant", respectively, including "4. The appearance is small after folding", "11. The folding chairs can be combined and moved to the desired position according to the desired quantity, and the handling speed is fast", "14. Folding chairs can be folded by stepping on the rear pole, no need to bend over", and "15. Folding chairs can be combined with each other, so that multiple chairs can be transported at the same time"; after improving the items in the

fourth quadrant, the improvement of these items can be carried out again, though there is no urgent need.

There are nine items located in the "fourth quadrant", respectively, including "12. When the exhibition is set up, it can be quickly moved to the desired position, because it has been combined with the back of the chair, which reduces the alignment time. After arranging, release the fastener with one hand to open the folding chair. The installation speed is fast", "13. The folding chair can be opened by pulling the buckle with one hand to open the folding chair without bending over", "16. The chair can stand vertically after being folded and will not collapse", "17. The folding chair is crossed with feet. It can be stacked on top of each other, and the overall volume is smaller after storage", "18. The folding chair can be easily operated, reducing excessive repetitive movements of the body", "19. Removing repetitive injuries that require bending over for general operations", "20. Reducing alignment and arranging time", "21. Because two people can carry multiple chairs at the same time, it can reduce the manpower for installation", and "22. Reduce the time for arranging and unfolding folding chairs", thus expressing that people attach more importance to these than their satisfaction. The expectations are also areas that must be prioritized for improvement. If these problems can be strengthened and improved, the improvement will be more efficient.

According to the above IPA analysis results, to further improve the design of the folding chair, prioritize improving the nine items in the fourth quadrant, improve the service quality of the product, and place more importance of this product on customers satisfaction. The design is different from the traditional folding chair.

4. Product Design

This study explores the design activities for the "Fast Assembly and Deployment Capability of Folding Chairs". When solving the arrangement of the chairs in the exhibition, the exhibition staff must necessarily bend and open their hands to move them. The repetitive motion damage and the pinch hazard caused by the rapid arrangement and the arrangement of a large number of chairs need to be moved to the designated position one by one and the alignment of one by one requires a lot of time and labor costs, etc., according to the aforementioned research purposes. Based on the second chapter of the literature discussion and patent analysis, this study uses the 39 technical contradiction matrix of the third chapter TRIZ method and 40 invention principles, human-engineering human–machine system, and general design method to carry out the rapid assembly and deployment of folding chairs with innovative design of the function. After the product prototype design content is determined, the Inventor software is used to assemble and simulate the product parts, and then the product complete structure explanation diagram, product appearance diagram, production and processing parts diagram, product simulation operation diagram, etc. are drawn in sequence, and the details are as follows.

4.1. Folding Chair Overall Structure with Quick Assembly and Deployment Function

Innovative design for the rapid handling and deployment of folding chairs, analysis of the operation mode using the human factors engineering method, the TRIZ method to improve the folding chair design, and the most common use of the general design method are used to ensure the folding chair operation arrangement can be performed more quickly; the content is as follows.

The overall structure of the folding chair structure with rapid assembly and deployment functions is divided into four parts, including a chair frame, a seat cushion, a seat back, and a chair leg. It is a four-part assembled folding chair with quick assembly and deployment functions, as shown in Figure 22. The four parts are explained separately. (1) Seat frame: The frame needs to have a center of gravity and the angle of the force to support the seat cushion, the back of the chair, and the leg parts. Therefore, the design of the steel and structural strength of the material must be considered. (2) Seat cushion: The seat cushion device is on the chair frame and is a major factor in the displacement of the

center of gravity. In consideration of the strength of the displacement support, factors such as the comfort and breathability of the user are also considered. (3) Back of the chair: The back of the chair needs to consider the breathability and the comfort of the user. The back of the chair must also consider the distance between the back of the seat and the back of the seat and the weight of the support carried after the combination. Chair foot: The chair foot needs to consider the support and whether the center of gravity can be naturally unfolded after opening. In order to clearly describe the details of this product, this study will be based on the design and operation of the design of the folding chair for rapid assembly and deployment, folding for quick folding function design, folding chair quick handling, and layout function.

Figure 22. Folding chair exterior.

4.2. Folding Chair Design

In the exhibition arrangement of the chairs, the exhibition staff will need to quickly expand the folding chair. For this, the general folding chair expansion operation needs to be bent and the hands pulled apart, so that when the arrangement is large, the folding chair operation is not sufficiently simplified and pulling the folding chair may cause a pinch problem. In the case of repetitive motion injuries, the rapid deployment of the folding chair in this study requires rapid deployment and safety and reduces repetitive motions, simplifying the movement and ensuring the folding chair unfolds quickly and safely.

According to the second chapter, the related literature discusses the principle of invention corresponding to the third chapter TRIZ 39 technical contradictions matrix and uses TRIZN No. 10 (pre-action principle): the cushion sponge is installed under the chair foot to cause the folding chair to develop the reaction force and the sound becomes smaller, to achieve the pre-action principle. No. 13 (reverse operation principle): the operation mode of pulling the ring by the person behind the folding chair is different from that of the general folding chair and the reverse operation principle is achieved. No. 25 (self-help principle): use the user to pull the ring in the back of the folding chair. When the chair foot is opened, it will be connected with the magnet of the seat cushion, and the weight of the chair foot will naturally expand downward to achieve the self-help principle. In the human-engineering system of human factors engineering, the repetitive movements are removed and the safety of the operation is increased. Finally, the fair use principle of the universal design and the simple and intuitive use principle are adopted to ensure the

folding chair operation is highly suitable for any operator and pull ring position. It is easier for users to detect.

The folding chair is divided into three parts, the chair frame, the seat cushion and the chair leg, and the three parts are combined to achieve a foldable function, and a magnet is arranged at the joint of the chair foot and the seat cushion to help the chair foot and the seat cushion. In the principle of shifting the center of gravity of the chair foot and the seat cushion, pulling the pull ring behind the front leg allows the chair foot to naturally unfold downward, so that the folding chair can be quickly deployed, and the chair foot is designed as a four-point support to cause the chair to be vertical. Standing, you do not need to hold the chair with your hands when you open it. Before the folding chair is opened, the chair legs are vertically stood at four points, and the rear leg of the front leg is released, so that the leg fasteners are loosened. At this time, the seat cushion and the legs are naturally unfolded and the magnets of the seat cushion and the leg are phased. Suck in the down to achieve a quick expansion. See Figures 23 and 24.

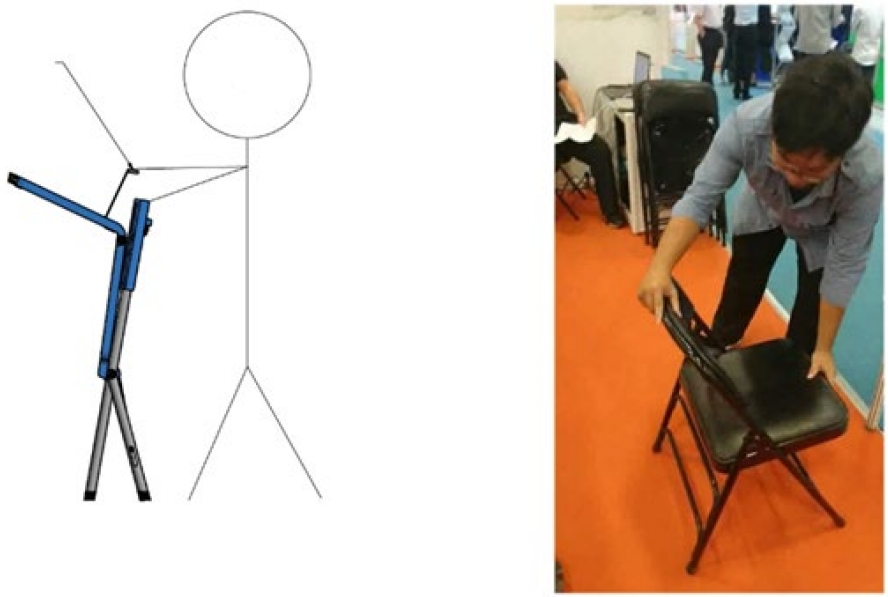

Figure 23. Diagram comparing the folding chair in this study and a conventional folding chair.

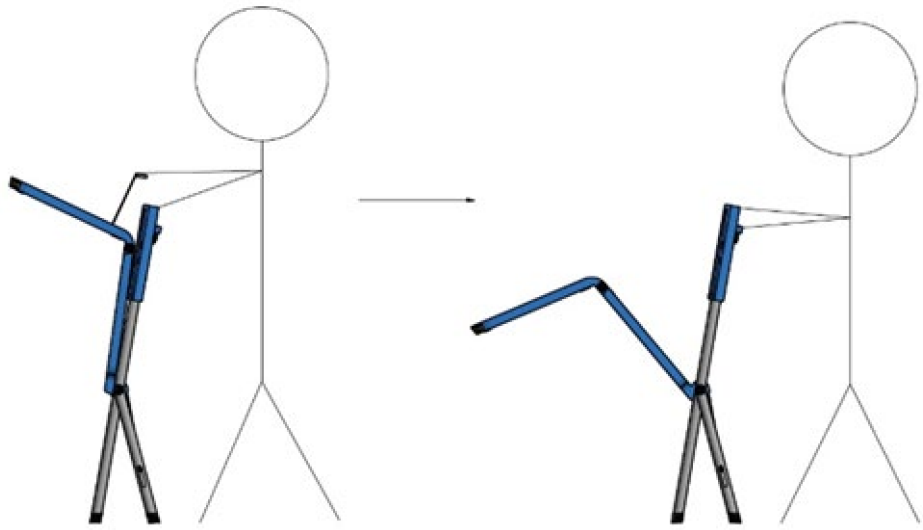

Figure 24. Diagram of folding chair pull ring operation.

4.3. Folding Chair Fast-Folding Function Design

In the exhibition arrangement of the chairs, the exhibition staff will need to quickly fold the folding chair when the exhibition is closed, and the folding operation of the folding chair needs to be bent and folded, so that when the arrangement is large, the folding chair operation is not simple, and the folding chair may cause the problem of pinching and repetitive motion damage, the rapid deployment of the folding chair in this study requires rapid deployment and safety and reduces repetitive movements, simplifying the movement to ensure the folding chair fold is fast and safe.

According to the second chapter, the related literature, and the third chapter's TRIZ 39 technical contradiction matrix corresponding to the invention principle, using TRIZ method No. 8 (balance principle): designed to fold the chair back and support the feet more, so that when folding there is enough balance and the folding chair will not collapse. No. 10 (pre-action principle) using the TRIZ method: a cushioning sponge is arranged at the rear of the chair and the seat cushion, so that the folding chair collapsing reaction force and sound becomes small, and the pre-action principle is achieved. No. 13 (reverse operation principle) using the TRIZ method: the use of a person to step on the pedal after the folding chair to achieve a quick folding, different from the general folding chair bending the hands to achieve the reverse operation principle. No. 15 (dynamic principle) using the TRIZ method: design the spring fasteners so that when the folding chair is folded, the spring rises quickly and fastens to achieve the dynamization principle. In the human-engineering system, the folding chair is used to remove the repetitive motion, to reduce the time of the arrangement, to solve the problem of the collapse of the chair after folding, and finally to ensure the folding person suitable for the fair use and simple and straight-through principle of the universal design. Any user uses and intuitively knows the position of the pedal. The folding chair is divided into three parts, the chair frame, the chair cushion, and the chair leg and the three parts are combined to achieve the foldable function and the pedaling rod and the elastic rope strap are arranged at the rotation shaft of the seat cushion, so that the pedaling step can be folded. The folding chair and the spring and the buckle are arranged on the back surface of the chair to automatically buckle when the chair foot and the seat cushion are folded, so that the folding chair can be quickly folded. In the open state, the pedal is tilted up by stepping on the rear pedal and the centrifugal force is turned up by the seat cushion to loosen the magnet of the seat cushion and the foot to be naturally merged and buckled in the fastener to achieve the quick collection function. See Figures 25 and 26.

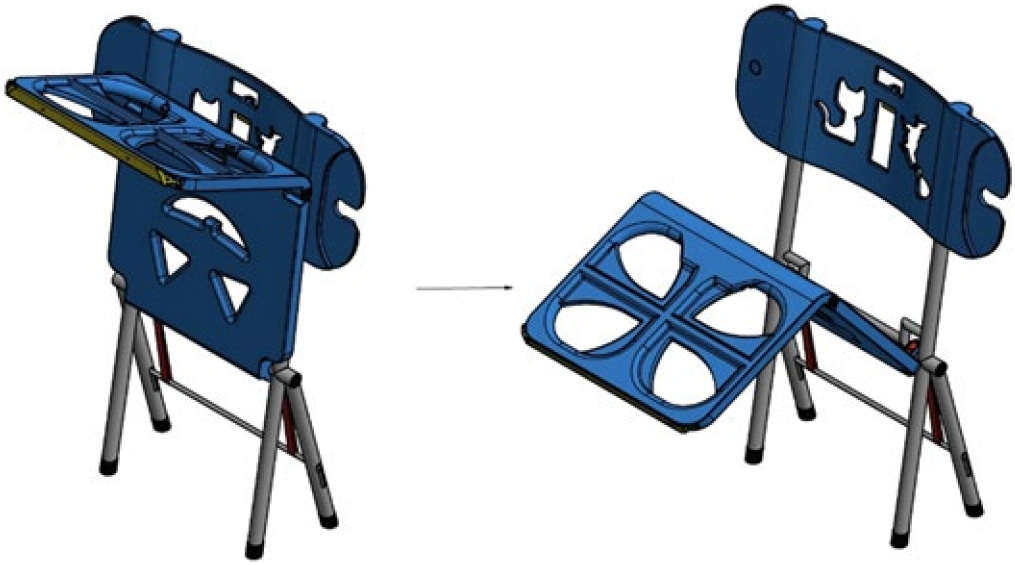

Figure 25. Diagram of the folding chair's unfolding process.

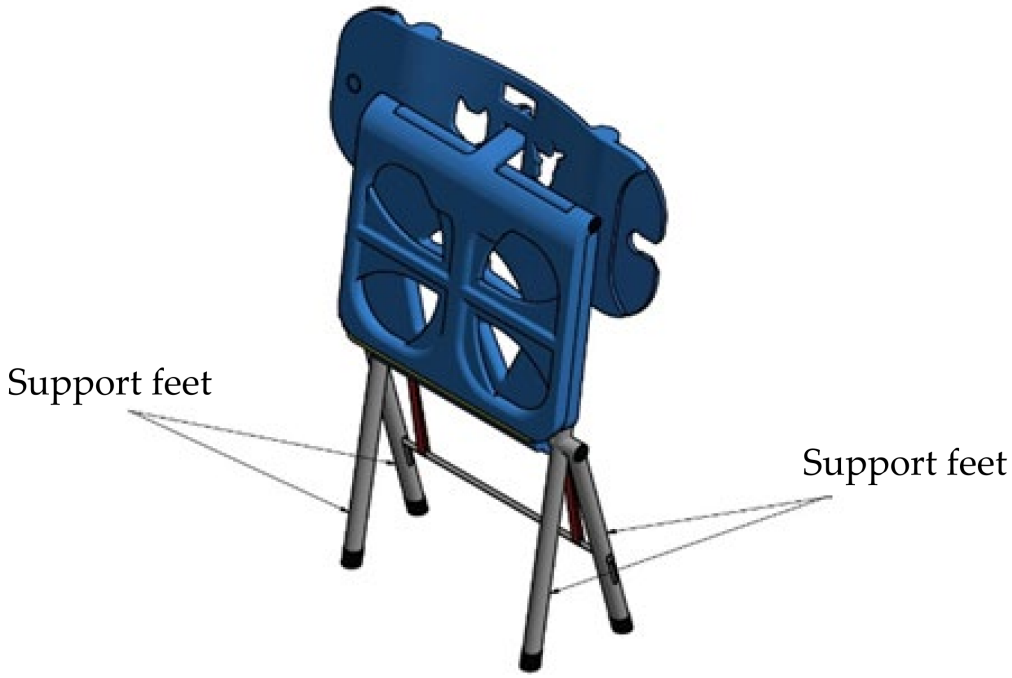

Figure 26. Diagram of the folding chair's support feet.

4.4. Folding Chair Design for Rapid Handling and Deployment

In the arrangement of the chair, the exhibition staff will need to quickly unfold or fold the folding chair during the exhibition and exhibition. However, when the folding and folding operation of the folding chair are arranged in a large number, the folding chair operation is not simple and must be carried one by one during the transportation. The specified positions are aligned one by one and the time and labor costs are un-necessary waste. In this study, the rapid handling and deployment functions of the folding chairs need to be quickly deployed and quickly transported.

According to the second chapter, the relevant literature discusses the principle of invention corresponding to the third chapter TRIZ 39 technical contradiction matrix, using the TRIZ method No. 1 (segmentation principle): the two sides are divided into joints and joint heads, so that the back of the chair can be connected quickly. No. 10 (pre-action principle) using the TRIZ method: the joint design rail is used to ensure the seat back can quickly engage to achieve the pre-action principle. No. 15 (dynamic principle) using the TRIZ method: design the joint spring fasteners and when the seat back is engaged, the springs are automatically fastened to achieve the dynamization principle. The human–machine system of human factors is used to connect the folding chair to transport multiple chairs and fold chairs. The folding chair can be automatically aligned according to the design guide rails after the seat back and the back of the chair are connected. Finally, the fair use of the universal design is used. With the principle of simple and intuitive use, any user can easily engage the back of the chair, distinguishing the joint of the seat back from the shape of the joint head, so that the user can quickly know the position of the joint head and the joint. Please refer to Figures 27–30.

The folding chair can be quickly opened and the folding function of the folding chair can be used to realize the setting function. The left and right sides of the seat back design can be used to extend the joint, the joint head, and the fastening function, so that the folding chair back and the back of the chair connect to each other, so that multiple folding chairs can be transported and quickly aligned at the same time to achieve fast handling and deployment functions, and to buckle the operation diagram and arrangement state.

Figure 27. Diagram comparing the folding chair of this study and conventional folding chairs in a standing position.

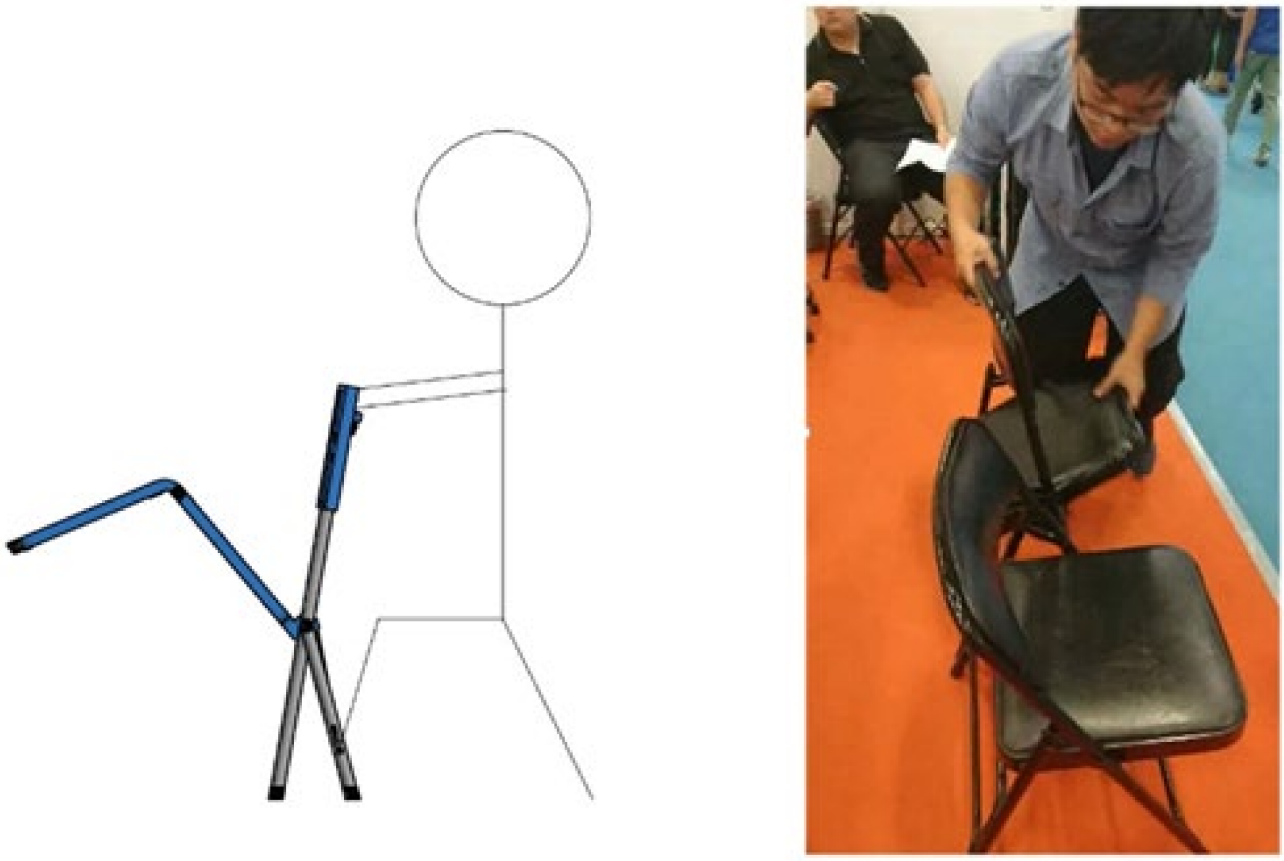

Figure 28. Diagram comparing the folding chair of this study and a conventional folding chair being folded.

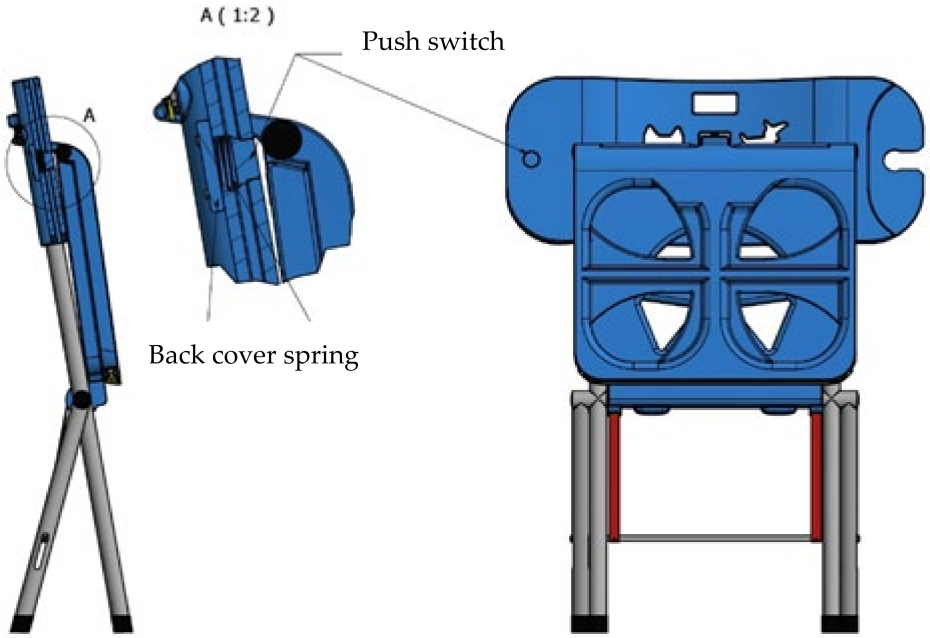

Figure 29. Diagram of the folding chair back joint device.

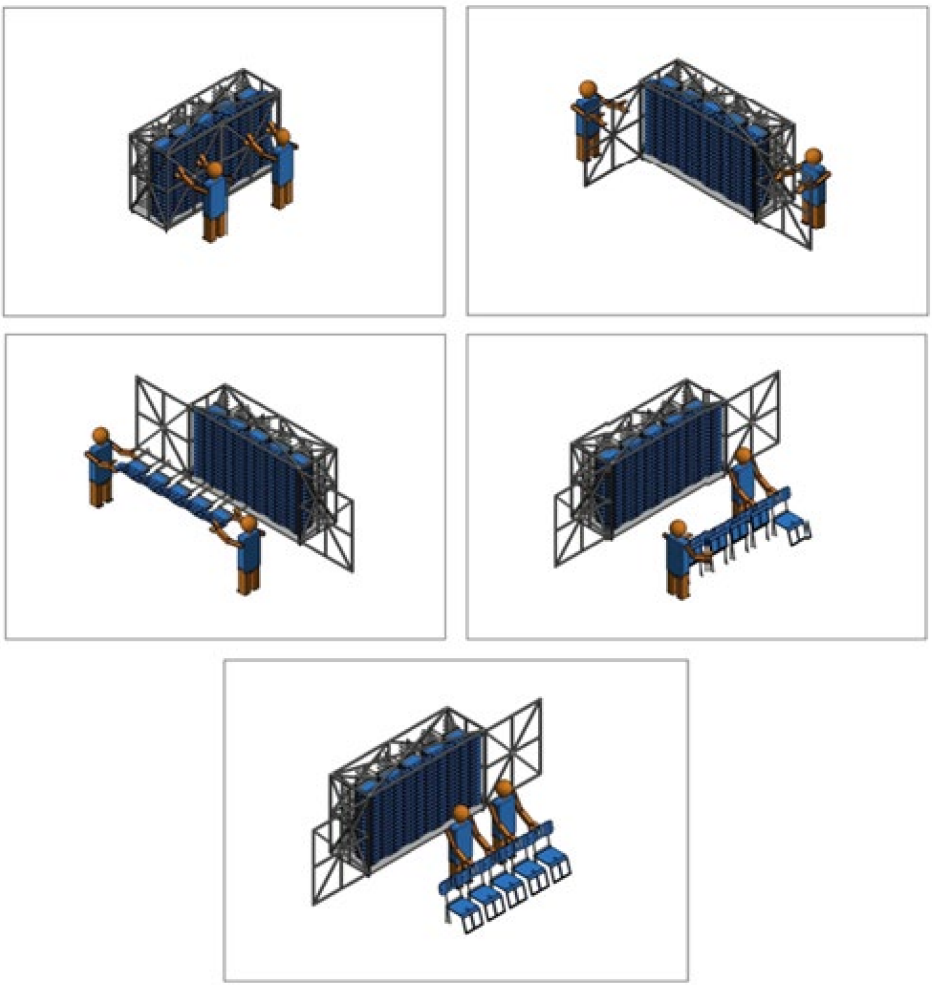

Figure 30. Diagram of the rapid set-up process of exhibition staff.

5. Conclusions

In the arrangement of the chairs, the exhibition staff will need to quickly expand the folding chair and the general folding chair expansion operation requires bending hands to pull the folding chair apart.

The folding chair needs to be bent over and folded. Because the folding chair folding operation is not simple enough, when the folding chair needs to be arranged in a large amount, the operator needs to repeatedly bend and use the action of both hands, which may cause the person to clip. Injury problems and repeated action injuries are a risk. This research introduces human factors engineering technology, TRIZ method design, and universal design, so that the folding chair no longer necessitates the repeating of the same action for a long time as much as possible and can also reduce the risk of operation damage and achieve the function of rapid deployment.

5.1. Folding Chair Quick Release Function

In the exhibition arrangement of the chairs, the exhibition staff will need to quickly expand the folding chair. Generally, the folding chair operation is not simple. Generally, the folding chair needs to be bent and the hands opened, so that when the arrangement is large, the folding chair requires use of the waist and hands. Repeated action damage is a risk. By pulling the ring and pulling the magnet with the foot and the seat cushion to achieve the quick expansion function and reducing the repetitive motion, the action that needs to be bent and merged with the hands is simplified as long as the chair is pulled behind the chair. The folding chair can be quickly and safely arranged in the exhibition to avoid heavy physical damage to the waist and hands.

5.2. Folding Chair Quick Folding Function

In the exhibition arrangement of the chairs, the exhibition staff will need to quickly fold the folding chair when the exhibition is closed, and the folding operation of the folding chair needs to be bent and folded, so that when combined in a large number of arrangements, the operation of the folding chair may cause a pinch problem. Repetitive action damage is a risk. By dividing the folding chair into three parts, namely the chair frame, the seat cushion, and the chair leg, the three parts are combined to achieve the foldable function, and the tread bar and the elastic rope are arranged at the rotation of the seat cushion, so that stepping on the pedal can fold the folding chair. When the spring and the buckle are arranged on the back of the chair, the seat and the cushion are folded automatically, and the action that needs to be used for the waist and the hand is simplified as long as the chair is standing. The use of the foot at the rear can achieve the function of folding the folding chair quickly.

5.3. Folding Chair Fast Handling and Deployment Function

In the arrangement of the chair, the exhibition staff will need to quickly expand or fold the folding chair during the exhibition. However, when the folding and folding operation of the folding chair is arranged in a large number, it must be transported to the designated position one by one during transportation, which will cause repeated hand and wrist injuries, which is an unnecessary waste in time and labor costs. The left and right sides of the back design extend the joint, the joint head, and the fastening function, so that the folding chair back and the back are connected to each other. Because the folding chair and the folding chair are connected together, the folding chair can be carried at the same time. The fast-handling function is achieved and the folding chair is connected with the folding chair, so it is not placed in the designated position to achieve the quick alignment function and only needs to step on the rear pedaling bar to ensure the folding chair can quickly collapse. At the same time, it is transported to the place of placement to achieve the function of rapid exhibition.

This design activity in the design process is conducted according to the TRIZ method, human factors engineering technology, systemic innovation methods of universal design,

and computer simulation design. However, due to the funding limitations of our team, we were unable to manufacture and mass produce the chair and could only present the design based on computer simulation and apply for a patent. When the activity funding is sufficient, we will create the product and do an actual comparison and test with a conventional folding chair. This design activity achieves the initial design concept and design simulation of the product design through a systematic innovation approach. Through this design activity, we can understand the problem of product improvement before product development so that we can do market research and evaluate the production cost for subsequent mass production and further reduce the cost issue of product design improvement.

6. Discussion

This design activity introduces an innovative system method for the innovative design of folding chairs, takes the TRIZ method as the main innovative design core, and then uses the human factors engineering method and general design to produce modifications to achieve the goal of innovative design. However, in the process of innovative design, there will be many challenges [55,56]. For example, when using the TRIZ method for innovative ideas, we must first have innovative design goals, and after we have goals, we need to find the parameters to be improved and the parameters to avoid deterioration and combine the 39 contradictions many times. The matrix is required to find the best contradiction matrix. When using the found invention principles to create ideas, everyone has different ideas in the process. This is also the most critical core of the entire TRIZ method. It is different. It is necessary to use the human-oriented orientation of human factors engineering to modify the results of the TRIZ method and to make improvements according to the universal design, so that the entire innovative design is humanized and universal.

Although this design activity introduces an innovative system approach to the use of innovative design for folding chairs, problems may still occur:

1. Folding chair fast-unfolding function: Although the folding chair can be quickly un-folded to achieve rapid deployment function, in the operation, one needs to pay attention to whether there are people in front, otherwise it will hit people standing in front and lead to injury. Additionally, one needs to pay attention to whether there is something near the unfolding space; otherwise, it will cause damage to objects and or the folding chair legs. This folding chair's fast-unfolding function cannot be operated in a small space. Although the safety of single person operation is solved through the systematic innovation method, it also causes the limitation of space use.
2. Folding chair fast-folding function: in the fast-folding function, one only needs to use the foot pedal to fold it up but should pay attention to keeping one's hands outside the range of the closing parts, otherwise it will lead to injury. When stepping, one only needs to gently step on the bar, and not vigorously. When the force is too great, it may cause the folding chair to become destabilized when unfolded and might cause breakage. This folding chair's fast-folding function uses an elastic belt to achieve the effect of folding, thus the life expectancy is shorter compared to that of conventional folding chairs.
3. Folding chair fast transport and exhibition function: the fast transport and exhibition function can increase the speed of transport, but there are certain restrictions on the number of joined chairs and the overall combined weight of the chairs. No more than 10 chairs should be moved, otherwise transportation may be hindered and damage may occur to joints, as well as incurring safety issues for the fast-unfolding function and fast-folding function when deploying exhibition seating. Although the folding chairs can be linked together through the folding chair fast transport and exhibition function, there is a limitation on the number of chairs that can be linked together.

7. Expected Impact

This design activity is used in the design activity of the folding chair for rapid assembly and deployment according to the systematic innovation method of the TRIZ method,

human factors engineering technology, and universal design in the design process. After the product prototype design content is determined, Inventor software is used to assemble and simulate product components and conduct preliminary novelty assessment. In the future, this innovative design can be used for market evaluation, mass production development evaluation, raising product design funds, and other activities. The contribution of this design activity is as follows:

Academia: through the systematic method of this design activity, Triz, human factors engineering, and universal design can be used to design products, perform preliminary novelty assessments, and apply this design activity to the design of other products to verify this design activity applicability.

Industry: through the method and simulation of this design activity, the shortcomings of the product before development and the evaluation before mass production are known in advance, thereby reducing the cost and time of design and development.

Society: through this design activity, the public can have the ability to turn ideas into designs, and through the public's ideas, more people can have ideas and patents, raise product design funds, and design products.

8. Patents

The research results have obtained the invention patent of the Intellectual Property Office, MOEA of the Ministry of Economic Affairs of the Republic of China (Patent number: I646927).

Author Contributions: All authors contributed meaningfully to this study. J.-R.X. and W.-S.H.—research topic; K.-C.Y., J.-R.X., K.-Y.L., W.-S.H. and Y.-H.S.—data acquisition and analysis; J.-R.X. and W.-S.H.—methodology support; K.-C.Y., K.-Y.L. and W.-S.H.—original draft preparation; K.-C.Y., J.-R.X., K.-Y.L., W.-S.H. and Y.-H.S.—writing review and editing. All authors have read and agreed to the published version of the manuscript.

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