Establishing an Intelligent Laundry Drying Rack Using System Innovation Theory

Ying-Hsiang Lin¹,²*, Yin-Ching Lee²,³ and Chia-Pao Chang²

¹Department of Industrial Education and Technology, National Changhua University of Education Changhua, Taiwan, R.O.C.
²Department of Industrial Engineering and Management, National Chin-Yi University of Technology, Taiwan, R.O.C.
³Mingdao High School, Taiwan, R.O.C.

*Corresponding author email: l12195@cc.ncue.edu.tw

Abstract. Laundry drying is a daily chore that every family endures. In Taiwan it is worse as the available area is limited, urban areas are densely populated, the winters are wet, and thunderstorms often occur on summer afternoons. Improving on the traditional laundry drying rack could make it an indispensable part of modern life improving the quality of life for everyone. This study uses TRIZ to improve the traditional bamboo design. First, this study collects and analyses literature related to the traditional bamboo design. Second, it then utilizes a contradiction matrix, 39 engineering parameters, and 40 invention principles in TRIZ to find the places that need to be improved and subsequently improves them. Finally, an intelligent laundry drying rack was created using sensors to detect light and rain. These synchronously trigger the control circuit, and drive the motor, so that the laundry is smoothly moved inside from outside, making laundry drying more convenient and safer.

1. Introduction

Taiwan is wet in winter. The urban areas are densely populated. The usable space on the balcony is often sacrificed to reconstruction to increase indoor usable space. Many families can only dry washed laundry indoors. However, drying laundry indoors can gradually increase the ambient humidity to more than 70%. This forms an ideal environment for the growth of mold spores, could induce asthma, and may cause symptoms such as breathing difficulties and organ inflammation, which is detrimental to your health. Sunlight is a natural "sterilant". The ultraviolet rays from the sun can kill a variety of harmful substances including mites and molds. At the same time, sunlight can dehumidify laundry, which also has a bactericidal effect [1]. The weather is hot and humid in Taiwan. Afternoon showers are common in the summer and lead to a rush to bring in the laundry that has been put out to dry before they are wetted by the rain [2]. Therefore, this imposes the burden to keep laundry dry on the elders in Taiwan. There have been many incidents where elders have fallen and broken their bones and even suffered life-threatening injuries when they hurried to bring the laundry in. Also, an intelligent drying rack with its monitoring system and electric drive is urgently needed to make life easier and to improve the safety of the elderly at home.

The Theory of Innovative (Inventive) Problem Solving is referred to as TRIZ [3]. The Theory of TRIZ was proposed in 1946 by G. S. Altshuller, a former Soviet Union inventor, who is also regarded as the father of TRIZ. Altshuller started to lead the research institutes of former Soviet Union universities and enterprises to form TRIZ research groups starting in 1946. They analyzed nearly 2.5 million pieces of
global high-level invention patents and put forward the basic theory on the problem of inventions based on dialectical materialism and systematic thoughts. Currently, many scholars have been devoted to the research of TRIZ, such as Lin et al. (2016), Chang et al. (2015), Lin & Lee (2020), and Huang (2020) [4] [5] [6] [7]. This study uses the contradiction matrix, 39 engineering parameters, and 40 invention principles in the Theory of Inventive Problem Solving (TRIZ) to find out the points that need improvement and then improve them.

2. Research Method

2.1. Research Process
First, to find out the issues and the technical contradictions after identifying the issues of an object. Second, to develop the 39×39 contradiction matrix in search of the 40 inventive principles. Third, to apply the feasible 40 inventive thinking solutions and logic thinking to consider the listed programs. Finally, to select the most suitable solution to solve the problem, as shown in Figure 1.

![Figure 1. Research flowchart](image)

2.2. Contradiction Matrix
Altshuller was the first one to propose the concept of system of innovation and invention. He observed each technical contradiction and developed a system accordingly, and summed up 39 engineering parameters and 40 innovative inventive principles. The first system regarding innovation and invention is known as the contradiction matrix. Besides, he developed the 39×39 matrix, which is a matrix using i to represent the improved characteristic and j to represent the avoidance of worsening result. Based on the inventive principles, each box grid represents a type of inventive problems, and each inventive problem has corresponding i and j coordinates. In the specific boxes of i and j, there are identification codes of the inventive principles applied to solve the problem [8].

2.3. 40 Inventive Principles
Recently, many efforts have been put in extending TRIZ to a broader application in the development of the research. Thus, 40 principles provide TRIZ users a way of thinking from principle to application. In the 40 inventive principles, each invention principle is a simple basic concept, and the derived ideas
3. The Intelligent Laundry Drying Rack Device Design Improvement

In Taiwan with its island climate, people should avoid drying laundry indoors as it creates excessive indoor humidity. When laundry is dried indoors, the drying process takes a long time which leads to a poor environment in which health can be severely compromised a "chronic suicide", "breathing in great quantities of mold spores", and "inhaling aspergillus can be fatal". Moreover, Taiwan often has afternoon thunderstorms in the summer, and the rain often comes suddenly, so it may be too late to collect the laundry. Therefore, a convenient, safe and intelligent laundry drying rack is urgently needed. With this system office workers need no longer worry about the laundry during the rainy season and the elderly who stay at home alone during the day can avoid falls and injuries caused when they rush to collect the laundry.

3.1. The Technical Contradiction of the Intelligent Laundry Drying Rack Device

After washing the laundry at home, use of the intelligent laundry rack will ensure that the laundry can dry as quickly as possible so that it can be brought in to save space. Indoor drying is slow and can cause chronic health problems. Laundry dries more quickly outdoors, but could get wet when it suddenly rains, or the elderly may be injured when they rush to collect the laundry. The technical contradiction of the intelligent laundry drying rack lies in "Weight of the moving object" and "Harmful factors acting on object from outside".

3.2. Development of Contradiction Matrix

As shown in Table 1, the appropriate i (improved characteristics) and j (results of avoided worsening) are found in the matrix, "Weight of the moving object" in column 1 corresponds to "Harmful factors acting on object from outside" in line 30, and the frame intersecting at the column and line represents suggested principles that can solve the current contradiction.

| The avoidance of worsening result(j) | 1 | … | 30 | … | 39 |
|-------------------------------------|---|----|----|----|----|
| improved characteristic(i)          |   |    |    |    |    |
| Weight of the moving object         |   |    |    |    |    |
| Harmful factors acting on object from outside |   |    |    |    |    |
| productivity                        |   |    |    |    |    |

It is found from the matrix that No. 18 principle "Mechanical vibration", No. 21 principle "Skipping", No. 22 principle "Blessing in disguise", and No. 27 principle "Cheap short-living" among the 40 invention principles can be applied mechanically, which is the best suggestion for the improvement of current technologies.

The contents of No. 18 principle "Mechanical vibration" are as follows.
1) Cause an object to oscillate or vibrate.
2) Increase the vibration frequency (possibly up to ultrasonic).
3) Make use of an object or system's resonant frequency.
4) Use piezoelectric vibrators.
5) Use combined field oscillations.

The contents of No. 21 principle "Skipping" are as follows.
1) Conduct an action at very high speed to eliminate harmful side-effects.
The contents of No. 22 principle "Blessing in disguise" are as follows.
1) Transform harmful objects or actions (particularly, the environment or surroundings) so that they deliver a positive effect.
2) Add a second harmful object or action to neutralize or eliminate the effects of an existing harmful object or action.
3) Increase a harmful factor to such a level that it is no longer causes harm.
The contents of No. 27 principle "Cheap short-living" are as follows.
1) Replace an expensive object or system with a multitude of inexpensive, short-life objects.

3.3. Thinking and Improving
This study will install a drive motor, controller, light sensor and rain sensor onto a traditional laundry drying rack (as shown in Figure 2).
1) Light sensor: used to detect light and measure the difference between day and night. The intelligent laundry rack will transfer the laundry from inside to outside on a sunny day, and from outside to inside at night.
2) Rain sensor: is used to detect whether it is raining.
3) Controller: receives the information sent by the light and rain sensors, and transmits the information to the drive motor for operation.
4) Drive motor: transfers the laundry rack from place to place through the transmission of information from the controller.

Figure 2. The intelligent laundry drying rack device
In this study, an intelligent laundry drying rack was created using sensors to detect light and rain. These synchronously trigger the control circuit, and drive the motor, so that the laundry is smoothly moved inside from outside, making laundry drying more convenient and safer.

4. Conclusions
TRIZ innovation theory was found to provide systematic and effective analysis for solving problems. The 40 Inventive Principles are one of the best known and commonly used tools of TRIZ. Initially, the "40 Inventive Principles" was focused on solving physical and chemical problems. Caused by the increasing impact of the industry solutions, there were some studies in searching for analogies of the 40 Principles in many things, not only products but also service. It can guide us to find the problem quickly, to analyse problems, determine the key, and then apply the thinking logic of TRIZ before adopting appropriate solutions. By TRIZ, the improvement and design of this research have helped the viability of problem solving, from problem thinking to the process of solving problems, through the applying of a design process method and logical thinking concept provided.
The contributions of this research with the use of TRIZ are as follows. First, the literature review shows that TRIZ is a kind of systematic theory with strong logical thinking, making persons with no advance
knowledge of TRIZ quickly understand and enter into a situation. Second, the 39×39 contradictions matrix and 40 invention principles used in this research are breakthrough solutions to problems in TRIZ, making readers clearly understand the process of problem solving with this method. Third, for the case of improvement, a lot of thinking in relation to logics is provided, which can be applied to other design improvements with the use of logical thinking. Fourth, "Intelligent home appliances" upgrade home appliances through ingenious innovations and the combination of monitoring systems and electric drives which control home appliances to make life easier. The intelligent laundry drying racks redesigned as a result of the research, transformation and innovative concepts of this study will not only improve poor ambient conditions caused from drying laundry indoors, it also ensures that the washing is saved from the rain, and improves the practical function of laundry drying racks.

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