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# A Systematic Innovation and Patent Design Around for Wheelchair in Health Care

Teng-Ruey Chang
Department of Industrial Engineering and Management,
Nan Kai University of Technology,
Nantou, Taiwan

Chung-Chuan Wang
Department of Multimedia and Game Science, Chung-Chou University of Science and Technology,
Chung-Hwa, Taiwan

Chung-Shing Wang
Department of Industrial Design,
Tung-Hai University,
Taichung, Taiwan

*Abstract*—**With the advent of an aging society, health care products and services have become increasing important for the elderly. Elderly aids are often regarded as the most crucial aspects of new product development in health care. Innovative methods in wheelchair design most commonly used the Theory of Inventive Problem Solving *(TRIZ)* and the Way of Oriented Innovation Strategy *(WOIS)* theories for new products. TRIZ innovation theory uses 39 engineering parameters and 40 inventive principles for innovative research and development. However, it cannot apply a global view to the whole system. WOIS theory uses systematic approach with a problem domain matrix to find contradictions and compensate for shortcomings from the TRIZ theory. In this study, we combined WOIS innovation theory and engineering parameters from TRIZ, using patent analysis techniques to improve existing product concepts in wheelchair design. This served to achieve the goal of both innovation and patent design around for new product development. In this paper, two cases of manual wheelchairs were investigated using TRIZ and WOIS innovation theory during the conceptual design phase to achieve the goal of patent design around.**

***Keywords - Innovation Algorithm, Theory of Inventive Problem Solving (TRIZ); Way of Oriented Innovation Strategy (WOIS); Patent Design Around; Wheelchair.***

## I. INTRODUCTION

As the society that we live in progressively ages, health care has become an increasingly important issue [1]. There is a greater demand on wheelchairs for the elderly. The inconvenience of traditional wheelchairs for long-term use has a profound impact on the elderly population [2, 3]. Creating a wheelchair that is easy to operate and suitable for different environments is of great importance for the elderly and physically disabled [4, 5, 6]. This study used an innovative theoretical framework as the basis for systematic development integrated with patent design around. By observing the market to find out advantages and disadvantages for all kinds of wheelchairs, we identified improvements and an innovative design for wheelchairs combined with a walker. Patent design around was used to verify innovation and development for the new wheelchairs.

This study presents two modified concept designs for current commercially available traditional wheelchairs with walkers. For the elderly and disabled wheelchair users, this provides a means for mobility and also facilitates adaptation to different environments.

The Theory of Inventive Problem Solving *(TRIZ)* combined with the Way of Oriented Innovation Strategy *(WOIS)* theories are proposed for new wheelchair design. TRIZ is a bottom-up method in product design, however, WOIS theory uses systematic approach from top-down with a problem domain matrix to find contradictions. In this study, we integrated WOIS innovation theory, engineering parameters from TRIZ and using patent around analysis techniques to improve existing product concepts in wheelchair design. Two cases of manual wheelchairs were proposed. The schematic diagram for this research is shown in Figure 1.

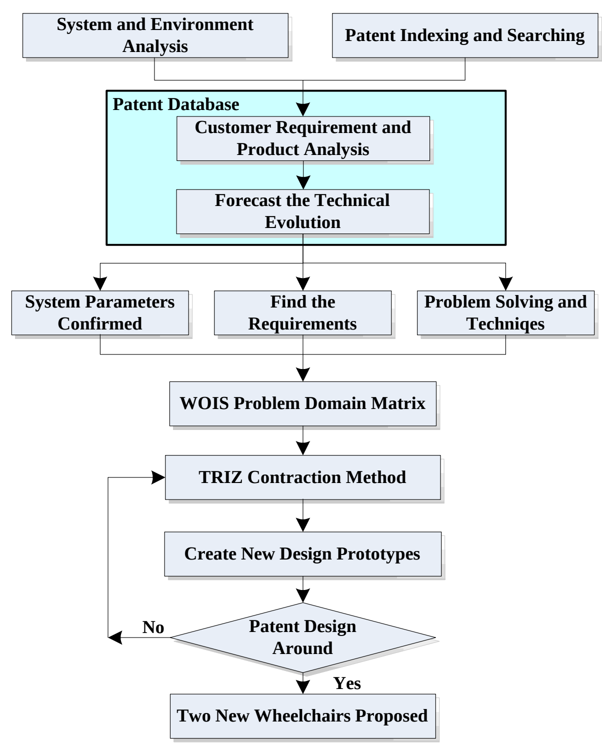


Figure 1. A Schematic Diagram for this research

## II. RELATED WORKS

This study provides a literature review and analysis for innovation algorithms, patent design around and wheelchair design [7, 8, 9].

### A. Innovation Algorithm

TRIZ is the abbreviation for "Theory of Inventive Problem Solving". It was proposed by Soviet Scientist, Genrich Altshuller in 1946 [10]. TRIZ combines engineering parameters and inventive principles matched to a contradiction matrix to list the possible problems that may arise during product research and development. The design of a contradiction matrix is useful for eliciting deteriorating influences brought about by one engineering characteristic on another. TRIZ principles were made from detailed definitions of 39 engineering parameters and 40 inventive algorithms. In the contradiction matrix, an analysis of subject vs. environment was used to redefine vacant matrix elements.

The TRIZ approach, however, was too focused on details and often missed the whole picture. To systematically considering the whole structure, Linde et al., [11, 12] proposed the WOIS (Way of Oriented Innovation Strategy) theory. WOIS is a development strategy that can be applied to the development of new products and processes and provokes results. The WOIS theory incorporates a number of methods from TRIZ theory. It emphasizes a type of hidden innovation and that innovation problems are often found in locations that are not easy to observe. We can find solutions to problems through the use of WOIS theory and experience of the technical teams. Any additional problems that were found during analysis and further technical parameters can be defined in the contradiction matrix. With the matrix we can identify key conflicts and obtain solutions for the contradictions. This method was verified through specific product development and has achieved outstanding results.

WOIS innovation theory is divided into three main stages [13]:

1) Direction stage: The direction stage is used to identify the main objectives. Proposed methods include: predicting technical evolution, present analysis, generation analysis and ideal solution analysis. This study proposed the use of patent analysis as a substitute method to identify major design goals. A viable alternative to that is to follow the normal design procedure, which utilizes sample questionnaires targeted to related professionals.

2) Determining strategy and finding contradictions: Determining strategy and the finding contradictions stage uses objectives and technical parameters obtained from the preceding analysis through technical team brainstorming to answer questions such as "What is the primary issue?" and "Why?" to further define a clear contradiction point. By integrating this into the problem domain matrix, we can identify what needs to be addressed along with technical contradictions.

3) Resolving contradictions stage: The main focus of this stage was to solve contradictions in the problem domain matrix and resolve related contradictions from the direction stage. Normally, answers for contradictions can be obtained from known innovation principles, such as: the 40 inventive algorithms, bionic science, technology and physical conflicts, etc [14]. Final obtained answers were then presented and evaluated.

### B. Patent Design Around

Patent design aims to go beyond existing technological restrictions so that infringement disputes may be avoided. Researchers in the past used patent design around and patent maps to help companies enter into new fields of technology. Over ninety percent of patents are recorded in the national patent database for each various country. Because of the large number of different databases, major patent design around literature can be found through each nation's intellectual property court rulings. Successful design around cases can then serve as references for practical operation.

The main methods for design around include using different techniques such as utilizing public domain and infringement analysis. Public domain techniques include prior art, deficits in operation manual and abandoned rights within patents. Patent design around has been used to assist new adopters to enter the market quickly and legitimately. Most published literature related to design around takes advantage of the public domain technique to look for different infringement angles and less through different technical means. Therefore, this study tried to combine patent analysis with WOIS innovation theory for patent design around and development during the product concept design phase.

## III. RESEARCH METHODS

The innovative system design methods proposed in this study combined design around and TRIZ contradiction theory to derive a WOIS correction method. WOIS innovation theory's biggest feature was the ability to construct a logical method to find a contradiction point to make up for the lack of efficiency in TRIZ and other general design methods. Through a literature review on the application of TRIZ methods, revision of WOIS innovation theory, and general design methods (brainstorming, KJ method, imagery chart, etc.), we discovered that TRIZ innovation theory has very successful results in solving contradictions and creating innovative steps [15]. However, determining design contradiction points still require developer experience.

WOIS and TRIZ innovation theories and general design all rely on developer experience when defining the initial direction and problems. This study presented this through patent analysis using expert opinions to define directions and problems for different cases. Main points were then entered into WOIS problem domain matrix for further analysis to show design contradictions from a value standpoint. Finally, the original WOIS theory was used to look for solutions to contradictions. Methods used during each phase are shown in Table I.

TABLE I. COMPARISON OF DIFFERENT DESIGN CONCEPTS

| | ***TRIZ innovation theory*** | ***WOIS innovation rule*** | ***Modified WOIS (this study)*** |
|---|---|---|---|
| ***Direction and problem definition stage*** | System operation and exploring opportunities. Function and attribute analysis | Technical evolution prediction, situation analysis | Integration of patent analysis |
| ***Determining contradictions or critical innovative points*** | Experience during design or new discovery and problem definition | WOIS problem domain matrix | Creating WOIS problem domain matrix |
| ***Solving contradictions or creating new innovative methods*** | Known innovative methods, e.g., the contradiction matrix, mass - field analysis, etc | Known contradiction solutions and innovative principles | Use of known innovative principles to seek answers for contradictions |

## IV. CASE STUDIES

This research used wheelchairs as case study examples with WOIS systematic innovative design and a TRIZ contradiction matrix to identify the most efficient innovative design approach for carrying out wheelchair concept design. First, a problem domain matrix was built for WOIS analysis. Contradiction can then be pointed out and solved to address critical items in concept design consideration. Two cases were proposed based on concepts for wheelchairs with the walkers.

### A. *WOIS Problem Domain Matrix*

Through patent analysis, the demand for the target product (customer demand) and the system parameters (technical methods) can be worked out. After that we can create a wheelchair WOIS problem domain matrix (Table II). By analysing the matrix, many contradiction breakthrough points were discovered. This study selected objective 1: patient examination and consultation, security and portability as the main objectives. We then use the importance factor in the system parameters to create a high demand for objective 1 (patient examination and consultation, security, portability and versatility) and a lower demand for objective 2 (cost) as an example for contradiction analysis in WOIS innovative theory design. Table III shows that to meet the "patient examination and consultation", "security" and "portability" design criteria we need to increase the number of mobile auxiliary components; however, if we want to lower costs, we need to reduce the number of auxiliary components. The contradiction point of these two goals was found by utilizing a WOIS problem domain matrix, which was then used for product innovation design in this study.

TABLE II. WOIS PROBLEM DESIGN MATRIX FOR WHEELCHAIR

| ***System parameters / Customer requirements*** | ***Wheelchair components*** | ***Number of connected parts*** | ***Number of wheels*** | ***Wheelchair material*** | ***Number of components*** | ***Weight*** | ***Diverse elements*** | ***Pedal*** | ***Water proof*** |
|---|---|---|---|---|---|---|---|---|---|
| ***Prevention of bedsores*** | ↑ | | | ↑ | | | | | |
| ***Mobility*** | ↑ | ↑ | ↑ | | ↑ | ↓ | | ↑ | |
| ***Auxiliary equipment*** | ↑ | | | | | | | | |
| ***Patient examination and consultation*** | | | | | ↑ | ↓ | | | |
| ***Safety*** | | ↑ | ↑ | ↑ | ↑ | ↑ | | ↑ | ↑ |
| ***Adjustability*** | ↑ | ↑ | | | | ↓ | | | |
| ***Comfort*** | | | | ↑ | | | ↑ | | |
| ***Portability*** | | | | | ↑ | ↑ | | | |
| ***Stability*** | | | ↑ | | | ↑ | | | |
| ***Multiple functionality*** | | | | | ↑ | | ↑ | | |
| ***Cost*** | ↓ | ↓ | | | ↓ | | ↓ | | |
| ***Ease of assembly*** | | | | | | | ↓ | | |
| ***Ease of operation*** | ↓ | | | | ↑ | ↓ | | | |

TABLE III. WHEELCHAIR WOIS CONTRADICTION ANALYSIS

| ***Required quality (Objective 1)*** | ***System parameters*** | ***Number of components*** | ***Required quality (Objective 2) - Cost*** |
|---|---|---|---|
| ***Patient checking and consultation*** ↑ | ↑ (Increasing) | ↓ (Decreasing) | ↓ (Down) |
| ***Safety*** ↑ | | | |
| ***Portability*** ↑ | | | |
| ***Multi-functions*** ↑ | | | |

### *B. Solving Contradictions*

WOIS contradiction solving matrix resources mainly come from experiences obtained during the previous analysis. This part of the study was replaced by patent analysis using an existing creative problem solving approach as reference. Existing creative problem solving includes 40 inventive algorithms of TRIZ, bionics, technical and physical contradictions, etc. These methods for problem solving can all be included and adjusted based on the different types of problems presented. In this case, the use of WOIS innovation methods with new contradiction analysis, while incorporating the latest product technology and concepts, can be considered as an upgrade to earlier TRIZ principles.

This study carried out contradiction analysis between objective 1: patient examination and consultation, security, portability, and objective 2: cost, in terms of "number of auxiliary components required" for the system. The method is shown below.

From the known principles and methods, the most common TRIZ concepts were used: contradiction matrix and single characteristic inventive principles for problem solving. We first matched up the 39 TRIZ engineering parameters to corresponding terms in the WOIS problem domain matrix to set up innovation rules. The nine most frequently used design rules were selected as the main problem solving principles. This included: 2 (removal), 28 (displacement mechanical system), 10 (pre-effect), 35 (change in material properties), 19 (harmonic motion), 13 (reversing), 29 (pneumatic or hydraulic operation), 6 (functionality), and 5 (combination), as shown in Table IV.

### *C. Innovative Design for Wheelchairs with Walkers*

This study used lifesaving wheelchairs as a case study example. Using the WOIS problem domain matrix obtained from previous analysis, we came up with nine principles of innovation. According to necessity and the possibility of production, we selected 29 (pneumatic or hydraulic structures) and 5 (combination) for a life saving wheelchair improvement plan. By comparing with patent analysis records we found that there were similar patents for pneumatic improvements. Therefore, this research used 5 (combination) for patent design around to create a newly improved model.

With an improved WOIS innovation principle combined with patent design around, this research proposed two wheelchair designs as case studies:

*1) A foldable walker with easy folding and extending functions*

This walker associated with a wheelchair contained easily folded and extended functions, see Figure 2(a), (b) and (c). Two front connected rods and two rear connected rods on the back are assembled with connected plates for easy operation. The elderly can use the walker individually. The design contained the following features: (a) compliant with mechanisms for giving it an effective life saving design; (b) a breakthrough from the traditional concept of wheelchair design, offering safety and simplicity for the user; (c) overall structure focuses on strong lightweight materials for easy maneuverability, See Figure 3.

TABLE IV. SOLVING WOIS PROBLEM DOMAIN MATRIX

| ***WOIS principles*** | ***TRIZ principles / TRIZ parameters*** | ***Cost*** | | |
|---|---|---|---|---|
| | | ***22 - Waste of energy*** | ***23 - Waste of materials*** | ***25 - Waste of time*** |
| ***Patient checks/ consultation*** | 33 Ease of use | 2,19,13 | 28,32,2,24 | 4,28,10,34 |
| | 36 Unit complexity | 10,35,13,2 | 35,10,28,29 | 6,29 |
| | 37 Complexity of controls | 35,3,15,19 | 1,13,10,24 | 18,28,32,9 |
| ***Safety*** | 13 Stability of objects | 14,2,39,6 | 2,14,30,40 | 35,27 |
| ***Portability*** | 1 Weight of moving object | 6,2,34,19 | 5,35,3,31 | 10,35,20,28 |
| | 33 Ease of use | 2,19,13 | 28,32,2,24 | 4,28,10,34 |
| | 36 Complexity of device | 10,35,13,2 | 35,10,28,29 | 6,29 |

Figure 2(a): Foldable Walker with Wheelchair

Figure 2(b): Folded the Walker

Figure 2(c): Extended the Walker

*2) Composite multifunctional wheelchair*

A composite multifunctional wheelchair combined traditional wheelchairs and walkers into a composite structure. The combination when folding the wheelchair and the walker is the main focus of this composite wheelchair (Figure 4). Connecting pieces can be found on the side of the wheelchair to link to the bottom of the handlebar of the walker. This allowed the user to easily set down the walker when getting up from the wheelchair for greater stability in walking. Both the wheelchair and the walker contained foldable connecting rods with foldable seating and a backrest made from high strength canvas. This allowed the wheelchair and walker to be folded into a smaller volume for storage or transport providing great practical application.

## V. CONCLUSION

Wheelchair users face the problem of being forced to spend long periods of time in the same position. This study proposed modified WOIS innovation theory with patent analysis to amend existing processes in order to develop a design around during the early concept design stage for new products. Two wheelchair designs were used as case studies to illustrate patents around design with WOIS innovation theory during a product conceptual design phase. We produced two innovative wheelchair designs that are able to assist the elderly or disabled individuals that lack individual mobility with high practical application. From concept to realization, prototypes in these two kinds of wheelchairs have been made. Some mechanism improvement and electrical control in wheelchairs will allow for future work.

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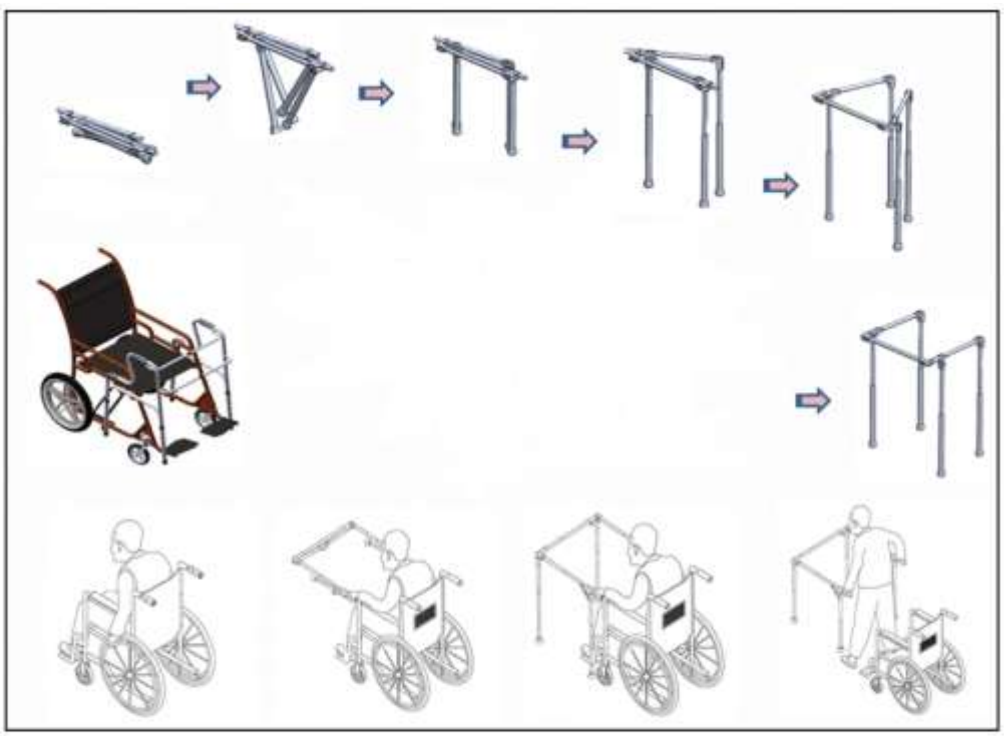

Figure 3: Processes for Foldable Walker with Wheelchair

Figure 4: A Composite Multifunction Wheelchair

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