



Faculty of Manufacturing Engineering

**INTEGRATION OF ANALYTICAL NETWORK PROCESS AND THEORY
OF INVENTIVE PROBLEM SOLVING FOR WHEELCHAIR
CONCEPTUAL DESIGN SELECTION**

Amira Farhana binti Mohamad Tar

Master of Science in Manufacturing Engineering

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INVENTIVE PROBLEM SOLVING FOR WHEELCHAIR CONCEPTUAL DESIGN
SELECTION**

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**A thesis submitted
in fulfillment of the requirements for the degree of Master of Science
in Manufacturing Engineering**

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UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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DECLARATION

I declare that this thesis entitled “Integration of Analytical Network Process and Theory Of Inventive Problem Solving for Wheelchair Conceptual Design Selection” is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature :

Name : Amira Farhana Binti Mohamad Tar

Date :

APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Master of Science in Manufacturing Engineering.

Signature :

Supervisor Name : Associate Professor Ir Dr Hambali Arep@Ariff

Date :

DEDICATION

Special thanks to my husband, my late father and my beloved mother for their unconditional support with my studies. Thank you very much for giving me a chance to prove and improve myself through all my walks of life. To my family, my lecturers and my friends, thank you so much for teaching and guided me. Hoping that with this research I have proven to all of you that there is no mountain higher as long as Allah is on our side.

ABSTRACT

In a general design process, development of criteria and brainstorming of ideas must be applied before generating design concept. Then, the selection of best design concept will be conducted. Nevertheless, in real market situations, the contribution of failure product marketed increase due to deficiency in design selection process. Thus, the research is aimed to develop a new framework for design selection at the conceptual design stage using the Theory of Inventive Problem Solving (TRIZ) and Analytic Network Process (ANP). The TRIZ method is intended to regulate its limitation by integrating simultaneously with the ANP technique. The ANP consists of two dependence feedback; outer dependence and inner dependence which to measure the accuracy of the result. The TRIZ identifies specific problem and ANP set a goal for a research project. The system parameter will be identified and implement into the contradiction matrices. The inventive problem solving is then generate and develop ideas to be assessed through ANP judgement using Super Decision™ software. The simultaneous integration contributes in solving the contradict problem and selecting the best design concept at the early stage of a design process. This integration is verified by a case study of a manual wheelchair as it assists designers in selecting the most optimum design concept. A case study has been conducted at Rehabilitation Department, Serdang Hospital with assistance from 3 expertise in wheelchair manual handling and technique. Different types of injuries may need different types of manual wheelchair. The discussion includes the main criteria needed in a manual wheelchair, main issues of a manual wheelchair, the process of using a manual wheelchair and et cetera. Therefore, the case study of a manual wheelchair is applied into the simultaneous integration method and generates 4 design concepts of a manual wheelchair. The validation of the selected design concept is described in term of sensitivity analysis, which is to generate the highest value among 4 design concept of a manual wheelchair. The sensitivity analysis was performed respect to each design concept and respect to each criteria. Therefore, Design concept 3 is selected as the best design concept due to its higher value in the normal weight.

ABSTRAK

Dalam proses reka bentuk umum, perkembangan kriteria dan idea sumbang saran mesti diterapkan sebelum menghasilkan konsep reka bentuk. Kemudian, pemilihan konsep reka bentuk terbaik akan dijalankan. Walau bagaimanapun, dalam situasi pasaran sebenar, sumbangan kegagalan produk yang dipasarkan meningkat disebabkan kelemahan dalam proses pemilihan reka bentuk. Oleh itu, penyelidikan ini bertujuan untuk membangunkan rangka kerja baru untuk pemilihan reka bentuk pada peringkat reka bentuk konseptual menggunakan Teori Penyelesaian Masalah Inventif (TRIZ) dan Proses Rangkaian Analitik (ANP). Kaedah TRIZ bertujuan untuk mengawal kelemahannya dengan mengintegrasikan secara serentak dengan teknik ANP. ANP terdiri daripada dua maklum balas pergantungan; pergantungan luar dan ketergantungan dalaman yang mengukur ketepatan keputusan. TRIZ mengenal pasti masalah tertentu dan ANP menetapkan matlamat untuk projek penyelidikan. Sistem parameter akan dikenalpasti dan dilaksanakan ke dalam matriks percanggahan. Penyelesaian masalah inventif kemudiannya menghasilkan dan mengembangkan idea yang akan dinilai melalui penghakiman ANP menggunakan perisian Super Decision™. Integrasi serentak menyumbang dalam menyelesaikan masalah bertentangan dan memilih konsep reka bentuk terbaik pada peringkat awal proses reka bentuk. Integrasi ini disahkan oleh kajian kes kerusi roda manual di mana ia membantu pereka dalam memilih konsep reka bentuk yang paling optimum. Satu kajian kes telah dijalankan di Jabatan Pemulihan, Hospital Serdang dengan bantuan dari 3 pakar dalam pengendalian dan teknik manual kerusi roda. Jenis-jenis kecederaan yang berlainan mungkin memerlukan pelbagai jenis kerusi roda manual. Perbincangan ini merangkumi kriteria utama yang diperlukan dalam kerusi roda manual, isu utama kerusi roda manual, proses penggunaan kerusi roda manual dan lain-lain. Oleh itu, kajian kes kerusi roda manual diterapkan ke dalam kaedah penyepaduan serentak dan menghasilkan 4 konsep reka bentuk kerusi roda manual. Pengesahan konsep reka bentuk yang dipilih diterangkan dari segi analisis kepekaan, yang menghasilkan nilai tertinggi di antara 4 konsep reka bentuk kerusi roda manual. Analisis kepekaan dilakukan berdasarkan setiap konsep reka bentuk dan setiap kriteria. Oleh itu, konsep Reka Bentuk 3 dipilih sebagai konsep reka bentuk terbaik berdasarkan nilai yang lebih tinggi dalam nilai normal.

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LIST OF ABBREVIATIONS

AHP	-	Analytic Hierarchy Process
ANP	-	Analytic Network Process
CBR	-	Case-based Reasoning
DMAIC	-	Define, Measure, Analyze, Improve, Control
GP	-	Goal Programming
HOQ	-	House of Quality
LCA	-	Life-cycle Assessment
MCDM	-	Multi Criteria Decision Making
QFD	-	Quality Function Deployment
SNA	-	Social Network Analysis
TOPSIS	-	Technique for Order Preference by Similarity to Ideal Solution
TRIZ	-	Theory of Inventive Problem Solving
VIKOR	-	Multi criteria Optimization and Compromise Solution
WOIS	-	Way of Oriented Innovation Strategy

LIST OF SYMBOLS

TM	-	Trademark
%	-	Percent

LIST OF PUBLICATIONS

Journal (Accepted)

1. Hambali A., and Amira Farhana M.T., 2018. Development of Integrated Analytic Network Process (ANP) and Theory of Inventive Principle (TRIZ) in the Conceptual Design Selection, *Journal of Engineering Science and Technology*. Vol. 13(9). pp. 2716-2733

Proceeding

1. Amira Farhana M.T., Hambali A., and Mohd Edeerozey., 2017. Development of an Integrated ANP and TRIZ for New Framework of Design Selection for Automotive at the Conceptual Design Stage. *Proceeding of Innovative Research and Industrial Dialogue'16 (IRID'16)*, pp. 97-98, May 2017

Symposium

1. M.T. Amira Farhana, A. Hambali, S.M. Nasiruddin, and M.H. Hidayah., 2015. A Review: Application of Polymer Based Composite for Automotive Bumper System. *Symposium Institute of Tropical Forestry and Forest Products (INTROP), UPM.*

CHAPTER 1

INTRODUCTION

1.1 Background

Finding a solution in conceptual design has to deal with the multi-criteria decision methods and making the right decision was very important to face the situation. There were normally multiple contradictory criteria that need to be assessed in deciding whether in our everyday lives or in professional settings. Many decision techniques have been successfully used, such as Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), Analytical Hierarchy Process (AHP), Analytical Network Process (ANP), Quality Function Development (QFD) and et cetera.

Among the techniques, AHP is generally simple and instinctive methodology that can be imply with other decision makers, hierarchically (Meade and Presley, 2002). However, many decision problems could not be structured hierarchically because they involve the interaction and dependence of higher level elements in a hierarchy on lower level elements (Saaty, 2003). Hence, Saaty has developed new methods named Analytic Network Process (ANP) which were generalized from AHP method. ANP is a multi-attribute approach to a decision which allows for the transformation of qualitative values into quantitative values and performing analysis on it (Meade and Presley, 2002). ANP does not require a hierarchy structure that takes more intricate interrelationships among the decision levels and quality (Meade and Presley, 2002).

Meanwhile, TRIZ is a problem-solving method first developed in the 1940's by a Russian patent engineer based on 40,000 innovative patents in identifying the original

problem and appropriate solution that has been used for resolving contradictions. This systematic tool generated innovative immutability to enhance ideation and performances. Each contradiction could be solved with appropriate solution principle which the efficiency of the designer's practices on the TRIZ theory (Howard et al., 2011).

In summary, the effectiveness of the problem-solving method and efficient design concept selection at the conceptual design stage were very important, which the most appropriate decision was to integrate both TRIZ and ANP method to develop a framework of design concept selection.

1.2 Problem statement

Since the industry was known to be very competitive, some issues need to be evaluated using problem-solving tools such as TRIZ which practiced in the manufacturing industry to figure contradiction issue. The enhancement of quality product required the combination of the problem-solving method with the other methods. Multi criteria decision making has been selected in order to enhance better quality of a product. ANP is capable to perform the analysis and necessary criteria for strategic assessment by considering the multiple dimensions of information (Meade and Sarkis, 1998).

TRIZ solved the contradiction using both 39 parameters and 40 inventive principles. Nevertheless, the solutions consist of more than one suggestions which would cause another steps that involved many factors with careful considerations to choose the best solution for the issues. TRIZ act as the systematic approach for product concept generation that created innovative ideas which completely considering product attributes from customer's demands using QFD, and to finalize innovative idea, ANP method was applied for an appropriate decision making (Lin and Han, 2012). In this research, ANP method was selected rather than

QFD method since ANP enable qualitative values formed into quantitative values for comparison analysis (Meade and Presley, 2002). Some researchers then develop the other techniques of integrated method in order to improve the function of TRIZ. To overcome the problem, the capability of ANP as a multi-criteria decision making it applicable in addition to the TRIZ methods.

The integration of TRIZ and ANP was proposed based on the deficiencies of existing problem-solving tools that could embody any conflict of interest and inconsistent decision. However, TRIZ method was said to impugn (Chechurin and Borgianni, 2016) and less used in innovation networks which its discovery has resulted in several failure outcomes (Rese and Baier, 2016). TRIZ is enshrined by problems connected with the dispersion of the theory, as well as difficult fundamental principles which characterize an unstructured collection of methods (Ilevbare et al., 2013) and some complex problems could not be controlled by traditional TRIZ properly (Cavalluci et al., 2010). While for ANP, its utilized the idea of a control hierarchy or a control network to deal with different criteria, yet leading to the analysis of benefits, opportunities, costs, and risks (Saaty, 1999). These approaches will overwhelm the shortcoming of TRIZ to create a new framework for selecting design concept at the conceptual design stage. Thus, matrices was developed for each criteria in the case study to determine the result using the integration of TRIZ and ANP. The importance of the integration method leads to the accuracy of design selection, in order to evade any deficiency.

1.3 Objectives

The aim of this research is to develop an integrated framework of design concept selection using TRIZ and ANP method at the conceptual design stage of a wheelchair.

To accomplish this, the following objectives as follows:

- i) To regulate the limitations of TRIZ method in solving contradict problem.
- ii) To propose a simultaneous integration of TRIZ and ANP in selection process at a conceptual design stage.
- iii) To verify the proposed integrated framework by conducting a case study for selection process in the manual wheelchair design.

1.4 Scope of works

The scope of the present research is using TRIZ and ANP approach as an integrated method in design selection process. Since the case study was applied in a manufacturing industry, the engineering contradiction used as the model of the problem which involves contradiction matrix, eventually lead to specific inventive principle to be the model of a solution. In addition to ANP in TRIZ method, complex mathematical which includes supermatrix that measure according to several different criteria was used in the research to improve the implementation of TRIZ in a manufacturing industry.

One of the manufacturing products involves the case study was a manual wheelchair in determining the most optimal design of selection design concept with a different function. The manual wheelchair was selected to contribute the improvement of existing manual wheelchair. This involved the alternate design concept of manual wheelchair which includes the volume of parts on the design. However, the case study only focuses on the performance,

safety, handling and ergonomic criteria of a manual wheelchair that reinforced the manual wheelchair itself. The case study was carried out by the short interview at Rehabilitation Department, Serdang Hospital, Selangor.

1.5 Significant of study

This research is to determine the best design concept of manual wheelchair that will facilitate the user. It is expected that this study will present the development of integration TRIZ and ANP for design selection process at the conceptual design stage. It is also expected that this study will show different design concept of manual wheelchair which has different functions during the usage of the manual wheelchair.

1.6 Outline of the thesis

The thesis is structured into 6 chapters. Chapter 1 is an introduction to the research study. Chapter 2 present the literature review on significant areas corresponding to the research topic. Next, Chapter 3 discovered the methodology implemented in this research. The new framework of integrated TRIZ and ANP is developed. The details of the design selection process in the framework are discussed in this chapter. Chapter 4 includes an industry survey held at Serdang Hospital to carry out a case study and applied both integrated TRIZ and ANP method in the case study to achieved validation of framework. The following Chapter 5 discusses the results and discussions of the design concept of a manual wheelchair for the best selection design concept. The discussion involved the inventive principle solution of TRIZ technique and the sensitivity analysis to verify the result obtained. The final Chapter 6 concludes the research works and encloses few recommendations for future works.