



**SELECTION OF BEST PLANT MAINTENANCE STRATEGY
USING ANALYTIC HIERARCHY PROCESS(AHP), TOPSIS-AHP AND
FUZZY-AHP**

This report is submitted in accordance with requirement of the University Teknikal Malaysia Melaka (UTeM) for Bachelor Degree of Manufacturing Engineering (Hons.)

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APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of Universiti Teknikal Malaysia Melaka as a partial fulfilment of the requirement for Degree of Manufacturing Engineering (Hons). The member of the supervisory committee is as follow:

.....
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ABSTRAK

Objektif projek ini adalah untuk memilih strategi penyelenggaraan terbaik dalam industri pembuatan wayar. Kesesuaian strategi penyelenggaraan akan memberi kesan langsung ke atas kos pengeluaran secara keseluruhan. Untuk memilih strategi penyelenggaraan yang terbaik adalah masalah kejuruteraan yang rumit. Oleh yang demikian, alat pembuat keputusan Multi-kriteria (MCDM) diperlukan. Terdapat beberapa alat MCDM yang popular seperti Proses Hierarki Analitik (AHP) dan Fuzzy-AHP. Menurut Ayhan (2013), ketidakpastian dan kekaburan penghakiman dalam prestasi kriteria dalam Tradisional AHP boleh dikurangkan dengan menggunakan Fuzzy-AHP. Dalam projek ini, empat kaedah Penyusunan Keputusan Multi-kriteria (MCDM) telah digunakan untuk memilih strategi penyelenggaraan kilang yang terbaik dalam industri pembuatan wayar, iaitu Proses Hierarki Analitik (AHP), Fuzzy-AHP jenis Trapezoidal, Fuzzy-AHP jenis Triangular dan Teknik untuk Perintah Pilihan oleh Keseragaman kepada Penyelesaian Ideal dengan AHP (TOPSIS-AHP). Strategi penyelenggaraan yang termasuk dalam pemilihan ialah Penyelenggaraan Pembetulan (CM), Penyelenggaraan Prediktif (PDM) dan Penyelenggaraan Berasaskan Keadaan (CBM). Melalui projek ini, telah didapati bahawa keempat-empat kaedah menunjukkan pemilihan konsisten di mana Penyelenggaraan Berasaskan Keadaan (CBM) dipilih sebagai strategi penyelenggaraan yang terbaik dalam industri pembuatan wayar. Beberapa cadangan bagi penambahbaikan kajian masa depan juga termasuk dalam projek ini.

ABSTRACT

The objective of this project is to select the best plant maintenance strategy in wire manufacturing industry. The suitability of plant maintenance strategy will directly impact on the overall production cost. In order to select the best plant maintenance strategy is a complex engineering problem. So, Multi-criteria Decision Making(MCDM) tool is required. There are several popular MCDM tools such as Analytic Hierarchy Process(AHP) and Fuzzy-AHP. According to Ayhan (2013), the uncertainties and vagueness of judgements in criteria's performance in traditional AHP can be reduced using Fuzzy-AHP. In this project, four Multi-criteria Decision Making(MCDM) methods have been applied to select the best plant maintenance strategy in wire manufacturing industry, which are Analytic Hierarchy Process(AHP), Trapezoidal Fuzzy-AHP, Triangular Fuzzy AHP and Technique for Order Preferences by Similarity to Ideal Solution with AHP(TOPSIS-AHP). The maintenance strategies that were included in the selection are Corrective Maintenance(CM), Predictive Maintenance(PDM) and Condition-based Maintenance(CBM). It is found that all the four methods showed consistent selection whereby Condition-based Maintenance(CBM) is selected as the best plant maintenance strategy in wire manufacturing industry. The conclusion also has been made from the project and the final selection of best plant maintenance strategy is justified. Several suggestions and recommendations for future study also included in this project for improvement.

DEDICATION

Only

my appreciated father, Lee Tiam Siew

my beloved mother, Chiu Suat Hong

my sisters, Ying Shi, Ying Li, Ying Hui and Ying Chin

for the moral support, cooperation, money, understandings and encouragement

Thank You So Much & Love You All Forever

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LIST OF ABBREVIATIONS

AHP	-	Analytic Hierarchy Process
FAHP	-	Fuzzy Analytic Hierarchy Process
MCDM	-	Multi-criteria Decision Making
TOPSIS-AHP	-	Technique for Order Preferences by Similarity to Ideal Solution with Analytic Hierarchy Process
FADSS	-	Fuzzy AHP Decision Support System
CM	-	Corrective Maintenance
PM	-	Preventive Maintenance
CBM	-	Condition Based Maintenance
CR	-	Consistency Ratio
RI	-	Random Index
CI	-	Consistency Index
PIS	-	Positive Ideal Solution
NIS	-	Negative Ideal Solution

LIST OF SYMBOLS

$\%$	-	Percentage
A	-	Matrix A
W_i	-	Priority vector
λ_{max}	-	Eigenvalue
r_i	-	Geometric mean of Fuzzy comparison value
α	-	Weightage of criteria in Fuzzy linguistic term l
β	-	Weightage of criteria in Fuzzy linguistic term m
γ	-	Weightage of criteria in Fuzzy linguistic term n
δ	-	Weightage of criteria in Fuzzy linguistic term s
w_j	-	Fuzzy weights
N	-	Crisp value
W	-	Overall Fuzzy weight
M_i	-	Defuzzified Fuzzy weight
N_i	-	Normalized M_i
V	-	Weightage of criteria in TOPSIS
S^+	-	Distance of criteria from PIS
S^-	-	Distance of criteria from NIS
C_i	-	Selective closeness of alternatives to ideal solution

CHAPTER 1

INTRODUCTION

This chapter includes background, problem statement, objective and scope of the project.

1.1 Background

This project is all about application of multi-criteria decision making tools which are traditional Analytic Hierarchy Process(AHP), Fuzzy-AHP and Technique for Order Preferences by Similarity to Ideal Solution with AHP(TOPSIS-AHP), in order to select the best plant maintenance strategy in wire manufacturing industry.

Maintenance is one of the common activities in manufacturing industries. The purpose of maintenance is to retain or restore damaged machining equipment or systems to achieve their maximum useful life. In a more complex manufacturing industry, the management need a planned strategy to execute necessary actions for maintenance which is called a maintenance strategy. There are several types of maintenance strategies such as corrective maintenance, predictive maintenance and condition-based maintenance. It is very important for a manufacturing industry to choose the most suitable maintenance strategy for their production line because it will directly influence the productivity and the overall production cost.

To select an optimal maintenance strategy is a Multi-criteria Decision Making(MCDM) problem. This is because there are several criteria, whereby each of the criterion has it's own sub-criteria that will contribute the overall efficiency of a maintenance strategy.

In this project, the judgements on criteria are based on the data from the journal "Selection of Plant Maintenance Strategy and Performance Enhancement of a Wire Manufacturing Industry

Using AHP” by (Parmar et al., 2016). In order to select the best plant maintenance strategy in wire manufacturing industry, Fuzzy Analytic Hierarchy Process(FAHP), a decision making tool which implemented artificial intelligence with Traditional Analytic Hierarchy Process(AHP) is applied to select the best plant maintenance strategy for the wire manufacturing industry. Technique for Order Preferences by Similarity to Ideal Solution with AHP(TOPSIS-AHP) will also be applied using the same judgements of criteria from the journal. The results from Fuzzy-AHP, TOPSIS-AHP and traditional AHP are then compared and discussed.

1.2 Problem Statement

According to a previous research from Parmar et al.(2016) in “Selection of Plant Maintenance Strategy and Performance Enhancement of a Wire Manufacturing Industry Using AHP”, the best plant maintenance strategy for wire manufacturing industry was determined through Traditional AHP only. Through literature reviews, there are several studies claim that Traditional AHP has limitations that may influence the accuracy of the final selection. In order to validate the accuracy of the final selection, other methods are applied to compare with the selection in Traditional AHP and discussion will be made.

1.3 Objective

- a) To select the best plant maintenance strategy using Traditional AHP, Trapezoidal Fuzzy-AHP, Triangular Fuzzy-AHP and TOPSIS-AHP.
- b) To compare the final rank orders made by Traditional AHP, Trapezoidal Fuzzy-AHP, Triangular Fuzzy-AHP and TOPSIS-AHP.

1.4 Scope

The scopes of this project are as follows:

- a) Focus on the best plant maintenance strategy in wire manufacturing industry only.

- b) Determination of the best plant maintenance strategy in wire manufacturing industry through four decision making tools only which are Trapezoidal Fuzzy-AHP, Triangular Fuzzy-AHP, Traditional AHP and TOPSIS-AHP.

1.5 Structure of Report

This report consists of 5 chapters, which are Introduction, Literature Review, Methodology, Result and Discussion and the last chapter is Conclusion and Recommendations.

In Introduction, the first section is the Background which introduces briefly on the maintenance strategies and multi-criteria decision making(MCDM) tools in selecting the best plant maintenance strategies for wire manufacturing industry. From the Background, a Problem Statement is summarized. Few objectives of this research are also presented in the Objectives. Then, followed by the scopes of this research because this research studies on specific portions only.

The second chapter is the Literature Review which discusses on the previous studies related to this research based on the objectives and scopes that have been stated.

The third chapter of this report is the Methodology where all the methods used in this research are explained in detail. A flow chart of this research are also presented in this chapter.

The fourth chapter is the most crucial part which is the Result and Discussion. This chapter explains the results obtained from the methods in the Methodology and discussion will be made based on the results.

The last chapter concludes the outcome of this project whether the objectives are achieved or not. Recommendations for future works are also included in this chapter for improvement.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Maintenance strategies is a crucial aspect in manufacturing industry. The suitability of the selected maintenance strategy will directly impact on the overall cost of the production. According to Salonen and Deleryd (2011), maintenance was a large part of the operating budget in organizations with heavy investment in machinery and equipment. The maintenance cost varies from 15% to 70% of the total production cost. So, selection of optimum maintenance strategy plays a crucial role in reducing production cost.

Multi criteria decision making problem is one of the most common engineering problems in manufacturing industry. So, it is important to study the methods or techniques that will help engineers to solve the problems. One of the most popular decision-making tools is the Analytic Hierarchy Process(AHP). An advanced version of AHP is the combination of Fuzzy Logic and Traditional AHP, which is called Fuzzy AHP. Another decision-making method is Technique of Order of Similarity to Ideal Solution(TOPSIS) which is also widely used in the industry.

There are several types of maintenance strategies found in the wire manufacturing industry. In this chapter, relevant information on the selection of maintenance strategies will be presented.

2.2 Maintenance Strategy Selection

According to Al-Turki et al.,(2014), maintenance in manufacturing environment is the most complicated maintenance as compared to construction, transportation and service business. Due to the highly competitive environment, manufacturing industries have to keep on reducing

the production cost and also improving the quality of the products. Meanwhile, maintenance in manufacturing requires special types of expertise to deal with highly technical equipment. It is also getting more expensive to hire expertise to deal with higher technologies equipment and the outsourcing choices are also limited. Hence, it is necessary to implement suitable maintenance strategies to improve the efficiency of the maintenance.

There were several studies on maintenance strategy selection. One of them is evaluation of optimum maintenance strategy for textile industry using combination of AHP and TOPSIS approach developed by (Shyjith et al., 2008). Another one was a study on choice criteria of maintenance strategy in automotive industries by (Pophaley & Vyas, 2010) using developed mathematic cost models which was then identified suitable for maintenance strategies selection in mass production industry. Besides, a Fuzzy AHP Decision Support System (FADSS) was used by (Pun et al., 2017) to determine the most cost effective and efficient maintenance strategies for facility management.

2.2.1 Types of Maintenance Strategies

Maintenance Strategy is a systematic approach to upkeep the facilities and equipment. It involves identification, researching and execution of many repairs, replace and inspect decisions (Gandhare and Akarte, 2012).

Basically, maintenance strategies can be divided into two main groups which are Corrective Maintenance (CM) and Preventive Maintenance (PM). Corrective Maintenance is reactive maintenance where maintenance actions only executed after a machine breakdown where obvious failure has been located. While Preventive Maintenance is a proactive maintenance to reduce the probability of failure or degradation of functionality of the machine through maintenance actions at a predetermined interval or condition, namely Condition Based Maintenance (CBM).

In Figure 2.1, an overview of the available types of Maintenance Strategy developed by (Niu et al., 2010).

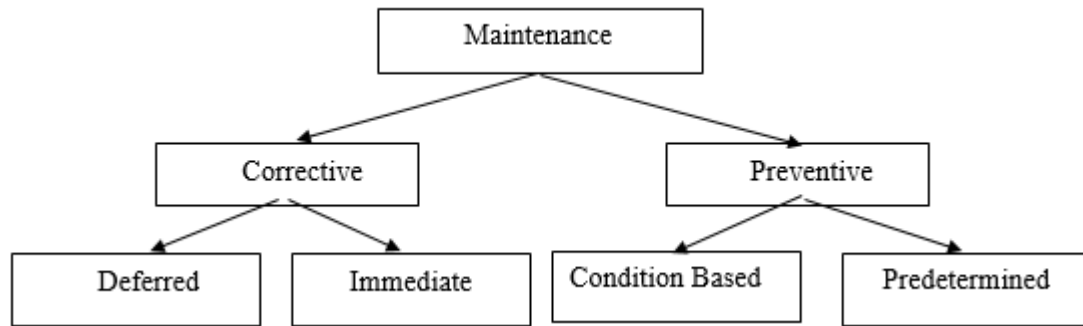


Figure 2.1: An overview of types of maintenance(Niu et al., 2010).

2.2.1.1 Corrective Maintenance

Corrective Maintenance is also known as reactive or breakdown maintenance. The maintenance actions only executed after a break down or failure of machine. Usually, this type of maintenance is unscheduled where the actions needed are unpredictable. Besides, corrective maintenance is more suitable to be implement at non-critical area where the capital costs are relatively small. Gandhare and Akarte (2012) found that such failure-based maintenance often may cause serious damage or failure to the facilities, personnel and equipment. The key of this strategy is to restore or repair the damaged machine or equipment as fast as possible once an obvious failure is detected. In case that only minor failures which do not interfere the production process, then the maintenance actions can be deferred to a suitable time.

2.2.1.2 Predictive Maintenance

Predictive Maintenance is also known as Preventive Maintenance where the intention is to avoid the break down or failure of the machines. The idea of this method is to predict or forecast the wear and tear of the machine's parts by using mathematical models and the corrective actions are planned accordingly.

2.2.1.3 Condition Based Maintenance

Condition Based Maintenance is a maintenance under Preventive Maintenance. This type of maintenance involves instrumentations of equipment to monitor the conditions. In recent years, developments in condition-monitoring equipment have allowed extensive analysis of data and better tools for monitoring. An ideal Condition Based Maintenance will achieve minimum time spent for maintenance, down time and spare part cost.

There are several popular condition-monitoring techniques. One of them is vibration analysis. Vibration analysis usually applied at machining parts that have dynamic actions such as reciprocating and rotating. Examples of the machining parts are reciprocating engines, roller bearing and fan. Another technique is oil analysis. This analysis will monitor the chemical composition of the oil and the foreign materials. The changes in pH, viscosity and water content will indicate the equipment's condition. Condition Based Maintenance is costly because involving extra high technology tools for conditions monitoring but it has several benefits over predictive maintenance which are reduction in maintenance cost, improvement in system reliability and reduction in number of maintenance operations which reduce human error influences.

2.3 Multi Criteria Decision Making (MCDM) Method

Multi Criteria Decision Making is one of the most common tasks in engineering world. When a decision needs to determine based on several criteria and sub-criteria, a suitable MCDM method need to apply in order to evaluate the ranking of the alternatives. Several Methods have been developed in solving MCDM problem such as Analytic Hierarchy Process (AHP), Fuzzy Analytic Hierarchy Process (FAHP) and Technique Order of Preference Similarity to Ideal Solution (TOPSIS).

2.3.1 Analytic Hierarchy Process (AHP)

Analytic Hierarchy Process (AHP) was first introduced by Saaty in the 1970s. It is an MCDM approach by making judgements to each criteria and sub-criteria using a scale for pairwise comparison. Then, priority vectors are calculated to rank the alternative.