HYBRID SIX SIGMA-DMADV FRAMEWORK WITH LEAN, FAHP AND TRIZ APPLICATIONS FOR AUTOMATIC INSPECTION SYSTEM DEVELOPMENT

by

KUMARAENDRAN A/L PURUSHOTHAMAN
(**1732422490**)

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School of Manufacturing Engineering
UNIVERSITI MALAYSIA PERLIS

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LIST OF ABBREVIATIONS

DMADV	Define, Measure, Analyze, Design, and Validate
DFSS	Design for Six-Sigma
TRIZ	Theory of Inventive Problem Solving
FAHP	Fuzzy Analytic Hierarchy Process
DMAIC	Define, Measure, Analyze, Design and Verify
VOC	Voice of Customers
QFD	Quality Function Deployment
DFMEA	Design Failure Mode Effect Analysis
ARIZ	Algorithm of Inventive Problem Solving
CCR	Critical Customer Requirement
HOQ	House of Quality
CA	Customer Attributes
EC	Engineering Characteristics

LIST OF SYMBOLS

r_i	Geometric fuzzy comparison value
w_i	Fuzzy weight of a single criterion
M_i	Non-fuzzy weight of selected criterion
N_i	Normalized non-fuzzy relative weight

Kerangka Hibrid Six Sigma-DMADV Menggunakan LEAN, TRIZ dan FAHP untuk Pembangunan Sistem Pemeriksaan Automatik

ABSTRAK

Mengawal kejadian kerosakan adalah satu cabaran utama bagi organisasi perkilangan yang berusaha meningkatkan kedudukan persaingan mereka dalam pasaran global hari ini. Fokus kajian ini adalah pada proses lamina pita pelekat menggunakan mesin berasaskan *nip roller*. Peratusan kecacatan dalam pengeluaran proses lamina ini terutamanya kecacatan yang kritikal kepada pelanggan adalah tinggi, dan memerlukan perlaksanaan sistem pemeriksaan automatik. Kaedah *Six Sigma-DMADV* berpotensi untuk memastikan reka bentuk sistem pemeriksaan automatik yang dibangunkan adalah optimum. Namun demikian, kajian-kajian sebelum mendapati kaedah pendekatan *DMADV* tradisional mempunyai kelemahan yang tertentu. Oleh itu, untuk kajian ini, pendekatan hibrid berasaskan *DMADV, LEAN, FAHP* dan *TRIZ* dan digunakan untuk melaksanakan pembangunan sistem pemeriksaan automatik. Analisis menunjukkan bahawa majoriti jenis kecacatan yang kritikal kepada pelanggan adalah berpunca dari masalah penggelek *nip roller* mesin lamina. Seterusnya, pendekatan *LEAN* menggunakan *FAHP* di aplikasi bagi pemilihan alternatif reka bentuk sistem pemeriksaan automatik dan kaedah *DFMEA* menggunakan TRIZ di aplikasi bagi memperbaiki kelemahan reka bentuk yang dipilih. Verifikasi prototaip pemeriksaan automatik yang dibina didapati mempunyai prestasi serta fungsi yang optimum. Didapati, pendekatan hibrid berasaskan *DMADV, TRIZ* dan *LEAN* boleh menyumbangkan kaedah reka bentuk yang lebih tersusun dan sistematik berbanding pendekatan *DMADV* tradisional.

Hybrid Six Sigma-DMADV Framework with LEAN, TRIZ and FAHP Applications for Automatic Inspection System Development

ABSTRACT

Controlling the occurrence of defects is a major challenge for manufacturing organizations that are seeking to enhance their competitive position in today's global market. The focus of this research is on the lamination process of adhesive tapes which are based on nip rollers. Percentage of defects and particularly defects critical to customers in the lamination process of adhesive tapes is high and implementation of an automatic inspection system is necessary. The Six Sigma-DMADV methodology is a potential approach to ensure that an optimised automatic inspection system is developed for the process. However, previous researches indicate the traditional DMADV method has certain drawbacks. Hence, for this research, a hybrid approach based of DMADV, LEAN, FAHP and TRIZ is applied for the development of the automatic inspection system. Analysis indicates that major defects that are critical to the customers are sourced from the lamination machine nip roller problems. Further, the LEAN approach is applied on the FAHP for the selection of best fit design among multiple design alternatives considered, whereas, the TRIZ is applied on the DFMEA method to improve the design selected. Verification of the developed automatic inspection system prototype reveals that the developed prototype has optimised performance and function. It was found that the Six Sigma with DMADV, TRIZ and FAHP approach facilitates a more structured and systematic design compared to the traditional DMADV approach.

CHAPTER 1 : INTRODUCTION

1.1 Introduction

This chapter is divided into five sections. The first section gives an overview of the research project background, the second section discusses the problem statement of the research, the third section deals with the research objectives, the fourth section includes the research focus and delimitation and the fifth section describes the overview of this thesis.

1.2 Research Project Background

In accordance to the escalation of heavy competition in the current industrial market, organisations attempt to implement various continuous improvement activities to their manufacturing processes. Common improvement activities which are favoured are those activities which increase overall performance by optimising the usage of available resources. For instance, LEAN manufacturing, total quality management and Six Sigma are examples of methodologies implemented for improvement activities in the manufacturing process. Among these methods, Six Sigma methodology is widely applied to enhance productivity, improve quality and reduce process variation. By applying detailed analysis, this methodology identifies the root causes of the problems (Aligula, Kok, & Hock Kheng, 2017). In the product or system development context, Six Sigma's Define, Measure, Analyse, Design, and Validate (DMADV) approach is vastly used for developing new product or process. DMADV focuses on designing or redesigning products or processes, thus, this approach is commonly recognised as the Design for Six-Sigma (DFSS).

The DMADV process is not only adopted by practitioners in organizations which are involved in the manufacturing, but also by researchers in various other fields as well. The methodology facilitates a systematic thinking process for problem solving that offers the most optimal alternatives for the solutions. Potentially, several other improvement methodologies can be applied conjointly during the implementation of the DMADV methodology. In current study, the development of inspection system is facilitated through DMADV application. Inspection system is developed to automatically detect adhesive tapes with defect percentage above threshold value as reject. In addition, hybrid approach using Theory of Inventive Problem Solving (TRIZ) and Fuzzy Analytic Hierarchy Process (FAHP) are applied during the implementation steps of DMADV to obtain optimum results.

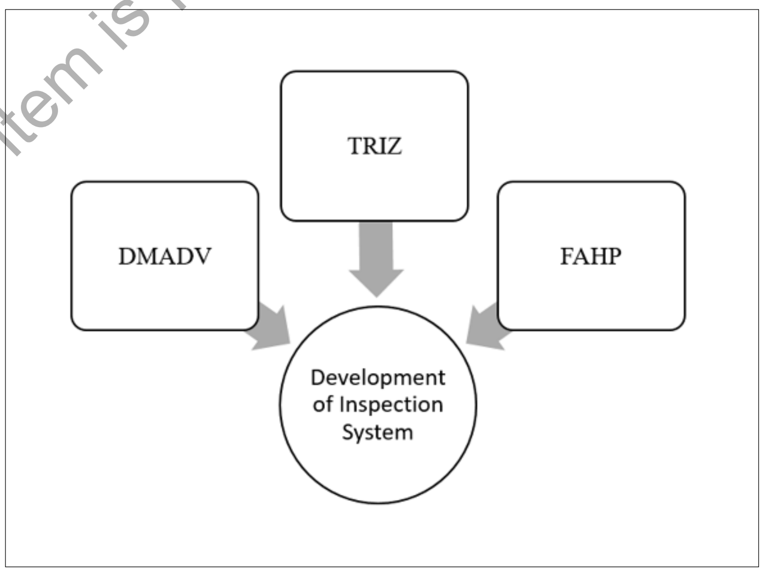

Figure 1.1 Development of Inspection System

1.3 Case Study Overview

Application and consumption of adhesive tapes have multiplied into several industrial and domestic areas. Additionally, in accordance with the advancement of machines for the manufacturing of adhesive tapes and discovery of new adhesive materials the adhesive tapes are currently manufactured for fields such as food, medicine, wood-based industry, textile and others (Huang, Chen, & Chang, 2010).

A case study in this research project is performed at a processing industry in Malaysia. The company is adhesive tape-based industry that produces various types of adhesive tapes for domestic and industrial application. The production floor is the main area where major activities and processes are carried out by workers and machines. The case study is carried out at the lamination station of the main production line in the company. The production line consists of five processes as shown in Figure 1.1. This production line involves different stages of machine processing such as liner unwind, silicone coating, adhesive coating and lamination. Raw liner is run with silicone coating and followed by adhesive coating. Coated tapes are rewind into laminator machine for liner attachment. Finally, the rewinding is performed until required length of the adhesive tape is obtained. Current study is focussed on the laminator machine as past historical data shows that it contributes to highest number of defects.

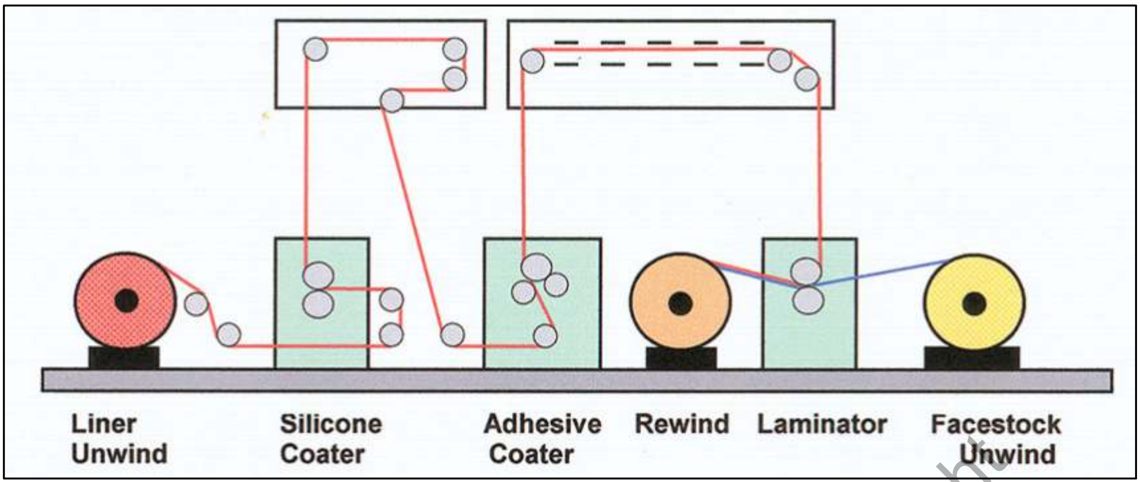

Figure 1.2 Adhesive Tape Production Process

1.4 Problem Statement

As customers increasingly demand high quality of the adhesive tapes, the pressure on the production quality of the adhesives tapes is also gradually increased. Processes involved in the manufacturing of adhesive tapes as discussed in previous section should be closely monitored as defects will seriously affect the quality of the finished tapes. Specifically, adhesive tape laminating machine which is used in the production of adhesive tape currently meets the general requirements of adhesive tape production, but it is not capable of detecting the related defects that are caused by mechanical factors such as tension instability and stress accumulation. Therefore, the development of automated inspection system as a key support system of existing adhesive tape laminating machine to detect the defects is critically needed.

The need of systematic and scientific approach in the development of an automated inspection system is necessary. Such approach will ensure the developed inspection system is efficient, effective and practical to be used in the laminating machine of adhesive tapes. A previous study conducted remarks that Six Sigma with DMADV steps is the most common and practical methodology to guide a new product or system development process (Aligula, Kok, & Hock Kheng, 2017). Further, another research points that DMADV has drawbacks in optimising developed solutions, thus, robustness of DMADV approach are enhanced with the incorporation of LEAN methodology and TRIZ. It is also highlighted that the hybrid approach is needed on DMADV to obtain synergized results that identifies critical factors, improve system development, optimise resources management and eliminate waste (Paslawski, 2013).

1.5 Research Objectives

The main objective of this research is to apply hybrid approach towards automatic inspection system development to minimize defect rate during adhesive tape production process. Following are the specific objectives in order to achieve the main objective.

i. To propose systematic hybrid methodology by integrating Six Sigma product development framework Define, Measure, Analyse, Design and Verify (DMADV), Theory of Inventive Problem Solving (TRIZ) and LEAN through Fuzzy Analytical Hierarchy Process (FAHP) to guide the development of automatic inspection system based on the case study described in section 1.3.

ii. To validate the proposed methodology structure in (i) based on the case study described in section 1.3.

1.6 Scope

The research will be carried out based on certain scopes, which are;

i. This research focuses on adhesive tape inspection only when it is in the post lamination process.

ii. The application of DMADV steps, TRIZ, FAHP and LEAN are directly considered on adhesive tape product structure and its mechanism.

iii. Inspection system that is developed focuses to counter three types of major defects on adhesive tapes which are bubble trap, adhesive picking and poor bonding between adhesive tape and liner.

iv. Only one adhesive tape lamination process area is selected for the case study, application and validation.

1.7 Thesis Overview

The overview of this thesis is as follows; Chapter two provides a literature review of the related subjects on hybrid six sigma methodology using DMADV, FAHP and TRIZ. Chapter three, deals with the methodology for the development of inspection system. Chapter four presents the validation, result and discussion of the developed inspection system, which a case study is carried out at processing industry in Malaysia. Chapter five presents the discussion of the developed inspection system and addresses with the conclusions and recommendations for future research.

CHAPTER 2 : LITERATURE REVIEW

2.1 Introduction

This chapter focuses on the literature review of Six Sigma methodology, Design for Six Sigma (DFSS), hybrid DMADV and industrial applications of Hybrid DMADV. The flow of the literature review is illustrated in Figure 2.1. In the topic of Six Sigma methodologies, the components of a Six Sigma methodologies and their significance are discussed.

In the next topic, the 5 steps of DFSS are discussed; there are define, measure, analyse, design and verify. In the topic of the hybrid DMADV, the concept and application of DMADV based on hybrid approaches are reviewed. While, in the topic of industrial application of hybrid DMADV, the emphasis is given to review the past industrial applications of hybrid DMADV and methods being applied. The final topic in this chapter discusses the findings of the literature review.

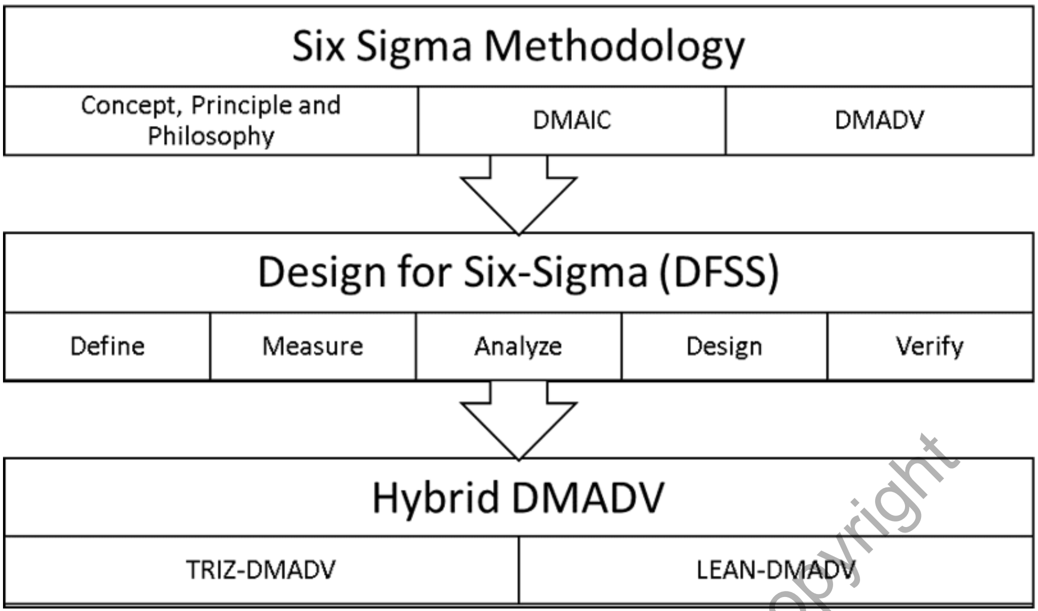

Figure 2.1 Flow of Literature Review

2.2 Six Sigma

Six-Sigma, a management strategy for business, was initially developed by Motorola in 1981 for improving the business processes involved. However, currently the application of Six Sigma has expanded into various industries and these industries are already experiencing large improvements. The focus of Six Sigma is to apply data analytical methods that keeps the variance of certain manufacturing process at a minimum level. Besides, Six Sigma also aims to meet customer requirements through implementation of measurement focussed process improvement that lowers the defect occurrence. In general, Six Sigma points out the cause of variances in certain process and facilitates the development of an efficient solution. Through the implementation of Six Sigma, customers are ensured to be satisfied as the defective products or services are reduced. In return, higher customer satisfaction assures that the revenue of organisation is improved and protected.

2.2.1 Concept, Principle and Philosophy

Fundamentally, the Greek lowercase symbol σ (Sigma) signifies the metrical or statistical conception that relates to a population's deviation and a measure of variation in process or distribution of a mean. Besides, in statistical control, it also known as the standard deviation. Previous study points that Sigma is a statistical approach that constitutes the variation amount found in a process corresponding to customer requirements or specifications (Ginn, Streibel, & Varner, 2004). Process operating at a 6σ level implies that it is 6 standard deviations away from average and acceptable limits of customer requirement. Which means, for a particular one million products produced only an average of 3.4 defects occurs (depicted in Table 2.1). Therefore, 6σ performance level is an approximation to perfect quality level for a particular process (Watson, 1993).

Table 2.1 Sigma Performance Scale

Sigma Performance Level	Defects per Million Opportunities	Process Yield	Estimated Cost or Poor Quality (% Revenue)
1σ	670 000	33%	>40%
2σ	308 537	69.2%	30-40%
3σ	66 807	93.32%	20-30%
4σ	6 210	99.38%	15-20%
5σ	233	99.9767%	10-15%
6σ	3.4	99.99966%	<10%

Due to variations, problem that cause defect occurrence in a process takes place. Ideally, a process with 0% variation should result in 100% yield. Variation reduction is the most important measure and remains as the core of Six Sigma methodology. The variations in Six Sigma are separated into two types and each type needs a different methodology for analysis and improvement.

The first type is the common cause variations which includes variations that are fixed (impossible for reduction) and variations that are possible to be reduced. This type of variation exists in bell-shaped normal distribution since it is caused by natural randomness. In practice, modification or change of whole system of the process is necessary to lower the common cause variations. The second type of variation is known as the special cause variation. The occurrence of this type of variation is not random in characteristics and normally in limited numbers but it has high effect on the cumulative value of variation. For example, occurrences that normally initiate the special cause variation could be machine breakdowns, introduction of new raw materials from other supplier or new standardized work procedures. High improvement potentials using needed resources are frequently found in these special cause variations. Hence, it is essential to differentiate the common cause variations with special cause variations for identifying potential improvement areas in a particular product, process or service (Bergman, Magnusson, & Kroslid, 2000).