



Faculty of Manufacturing Engineering (Industrial Engineering)

DEVELOPMENT OF FRAMEWORK FOR PLASTIC BOTTLE RECYCLING
TECHNOLOGY IN MELAKA USING ANALYTICAL HIERARCHY PROCESS

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**DEVELOPMENT OF FRAMEWORK FOR PLASTIC BOTTLE RECYCLING
TECHNOLOGY IN MELAKA USING AHP**

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**A thesis submitted
In fulfillment of the requirements for the degree of Master of Science**


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DECLARATION

I declare that this thesis entitle “Development of Plastic BottleTechnologyRecycling Framework in Melaka using AHP” 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 the candidature of any degree.

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APPROVAL

This report is submitted to the faculty of manufacturing engineering of UTeM as a partial of the fulfillment of the requirements for the degree of master manufacturing engineering (industrial engineering) with honours. The members of the supervisory committee is as follow.



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DEDICATION

This thesis is dedicated to my father and mother

ABSTRACT

The plastic bottle is a non-biodegradable polymer mostly containing carbon, hydrogen, and a few other elements such as chlorine, nitrogen and are indispensable to human. They Rapid growth of the world population led to increase in the demand of the plastics due to its vast applications in many fields. The non-biodegradability nature of plastic bottle necessitated for the investigation of an appropriate recycling model through the development of a new framework in an attempt to significantly reduce the problems associated with illegal dumping of used plastic bottles, pollution and environmental hazards. To avert these problems, three AHP recycling models (mechanical, chemical and thermal recycling model of plastic bottles) were developed and evaluated based on some important criteria which include cost, quality, efficiency and environment using data that was collected from SWM Environment SdnBhd and Tzu chi Foundation waste management worker in Melaka. The AHP models were used to Quantitative weigh and identify alternative recycling model that have similar outcomes in meeting the plastic bottle recycling technology based on the objective which were evaluated using the multiple criteria to validate the three models which are recycling model. Research findings showed that the mechanical model for plastic recycling is the best technology (37.9 %) followed by chemical recycling model (31.41%) and lastly thermal recycling model (30.70 %). The present study concludes that the mechanical recycling model for plastic bottle is suitable for recycling technology in Melaka based on the criteria that were used.

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LIST OF ABBREVIATIONS

Abbreviation

AHP	Analytical Hierarchy Process
DMT	Dimethyl terephthalate
EG	Ethylene glycol
PET	Polyethylene Terephthalate
HDPE	High Density Polyethylene
PVC	Polyvinyl Chloride
LDPE	Low Density Polyethylene
PP	PS Polypropylene Polystyrene
PCDFs	Polychlorinated dibenzofurans

CHAPTER 1

INTRODUCTION

1.0 Introduction

Human activities and lifestyles have been associated with high consumption of bottle drinks leading to the generation enormous quantity of different various plastic bottle wastes which are detrimental to the living environment (Oweis et al., 2005). Wastes threaten human survival and other living things as well as natural resources that support human existence. Consequently, over two decades ago, concern has raised over waste management and illegal disposal of waste resulting in environmental pollution and limited land space for landfilling of more recyclable waste such as plastic bottles (Abd El-Salam, 2010; Al-Khatib& Sato, 2009). It has become a well known fact that inappropriate disposal of plastic bottles poses a serious threat to the living environment (Coker et al., 2009; Sawalem et al., 2009).

Improper disposal of solid recyclable waste material such as plastic bottles directly and indirectly affects human health as well as the environment (Patwary et al., 2009a). Diseases such as cholera, skin infection, infectious can spread epidemic from unauthorized plastic bottle disposal mismanagement especially those that are used for drug packaging (Coker et al., 2009). Therefore, a need arises to urgently determine the appropriate hierarchical decision method that defines alternative recycling approaches so as to ensure safe handling and minimization of pollution from open burning of valued recyclable plastic bottles (Tachwali et al. 2007).

The Analytic Hierarchy Process (AHP) will be used in the present study to evaluate plastic recycling activities in Melaka, Malaysia. AHP is popular and widely used for multi-criteria decision making and allows for the evaluation of qualitative and quantitative criteria (Haas & Meixner 2009). AHP algorithm allows the decomposition of information into a hierarchy of alternatives and criteria which can be further synthesized to determine relative ranking of alternatives to plastic recycling processes in Melaka. Both qualitative and quantitative information can be compared using informed judgments to derive weights and order of priorities with respect to various recycling options.

1.1 Research Background

Plastic bottles comprise important part of the municipal solid waste. Plastic is mostly used for drinks, food, drugs, industrially and domestically owing to their low density to volume ratio and their chemically stable property (non-biodegradable materials). This means that used plastic bottles waste dumped into landfill sites for years without degrading could cause serious environmental problem as limited land space will be used to bury recyclable material that are economically important for the growing society (Hall et al., 2005).

There are seven various types of plastic having different chemical composition. These classes of plastic material comprise (1) Polyethylene Terephthalate (PET), (2) High Density Polyethylene (HDPE), (3) Polyvinyl Chloride (PVC), (4) Low Density Polyethylene (LDPE), (5) Polypropylene (PP), (6) Polystyrene (PS) and (7) other plastics (Hammaad, 2005). Different techniques are used to identify the chemical resin of plastic bottles among which include chemical methods (Hall et al., 2005), mechanical methods (Hammaad, 2005) which is often

referred to as electromagnetic methods that measures the electromagnetic spectrum absorption ratio of plastic materials. Electromagnetic technology is widely used for sorting and identification of plastic in the recycling industry.

Sorting of plastic bottles is challenging as bottles of different sizes are classified differently based on their orientation, shapes and composition. Bottles are usually compressed and crashed at the collection stage so as to reduce its volume. In the same hand, the collection cost is affected by its volume while the cost of sorted plastic bottles depends on their weight. The existence of different forms of plastics complicates sorting and classification stage (Tachwali et al. 2007).

Therefore, it becomes important to use metrics to address these difficulties so as easily classify plastic bottles irrespective of their structural orientation and shape. Plastic bottles can be sorted into various groups and is subject to their chemical resin, transparency and color. About 96 % of plastic bottles are PET and HDPE however; the efficiency and quality of recycling processes depend on the purity and accuracy of the sorted materials. Many studies have been conducted on the appropriate method for detecting and sorting different plastic materials considering their color, shape, weight and composition.

However, sorting of plastic bottles into different chemical composition categories adds to their recycling cost (Tachwali et al. 2007). A study has shown that light transmission through a plastic sample provides information about its polymer type (Dubanowitz, 2000) and distinguishes between pigmented HDPE (colored) and natural HDPE base plastics. Color-sorting is used to avoid recycling plastic bottles of different colors to ensure that one color is recycled (Stevens, 2003). These sorting methods provide recycling option were color of material is a concern to the final recycled product.

To identify plastic transparency, light transmission and reflection techniques using different types of photodiodes and LEDs are used (Crank et al., 2000). With all sorting categories available for plastic bottle recycling, the infrastructure and operational cost will rise as challenges to the success of an effective plastic bottle recycling system because of chains of processes involved to ensure that plastic bottles of like qualities are recycled. Sorting by chemical composition is expensive owing to the use of hardware such as spectrometers, lasers and X-rays to provide higher value plastic bottle output that is comparable to the initial product. This method facilitates the use of intelligent sorting algorithm which is required for plastic or color classification of plastic bottles. On the other hand, plastic bottle transparency sorting can be achieved with a cheaper and convenient method using a new framework based on AHP which could be cost effective compared to complex chemically sorted plastic bottles. In order to build a system that can achieve valuable sorting categories using cheap infrastructure, there is a need to consider recycling processes and the cost of each recycling stage. Concern over cost of recycling plastic bottles will help promote the recycling activities in Melaka as most households will generate income from using plastic bottles which were previously landfilled and illegally dumped along the street and water drain channels.

1.2 Problem Statement

Most recyclable plastic bottles are made from PET and HDPE which are expensive due to high domestic and international demand on the various applications. Plastics are made from petroleum products, as a result their price depends on the cost of highly depended exhaustible resource which fluctuates in market price as a result of limited oil well. It becomes obvious that high dependence on expensive oil and gas price result to increase in the cost of plastic bottles. Therefore there is a need to conserve plastic product through recycling. Although recycling provides viable alternative for efficient use of plastic bottles, the recycling processes are very complex and requires a low processing technique that are competitive with a fresh plastic product.

Securing a sustainable future in the use of plastic-based material requires the development of a new framework with fresh insights on the ability to see beyond the present constrained on using plastic bottles recycling practices in Melaka. Waste recycling practices are constrained by technological traditions of various parts of the world as well as the ability to match with the interdependent issues in recycling activities.

Recycling activities are constrained by lack of appropriated facilities as a result, most developing countries do not recycle recyclable products such as plastic bottles (Coker et al., 2009; Hassan et al., 2008; Patwary et al., 2009 a, b). Lack of awareness and shortage of skilled personnel on waste handling coupled with unavailability of suitable waste treatment and disposal were among the problems that impede waste recycling effort. To address these problems, the following research questions will be answered:

1. How are plastic bottle recycling processes implemented in Melaka, Malaysia?
2. Is there alternative plastic bottle recycling management framework that is compatible with plastic recycling processes in Melaka?
3. How is a plastic bottle recycling analyzed and what is the recommended framework for the recycling of plastic bottles in Melaka?

1.3 Objectives of the Study

The objectives of the present study are as follows:

1. To study the plastic bottle recycling process implemented in Melaka, Malaysia.
2. To propose an alternative framework of management of plastic bottle recycling process in Melaka, Malaysia.
3. To analyze and recommend an appropriate framework for managing the recycling process using (AHP) method.

1.4 Significance of the Study

Early studies use linear discriminant analysis (LDA) and partial least squares (PLS) to classify plastic material using their chemical composition (Stchur et al., 2002). LDA is an analytical method and PLS are well known method use to classify plastic materials. The found that the performance of classifiers is affected by environmental conditions. Although there are commercially available recycling systems (Hurd, 1997), the use of the newly developed framework will add to the existing technique and will improve the efficiency and performance of existing plastic recycling plant in Melaka. The integration of these enhance framework will

further provide options to overcome various limitations especially of those associated with high cost sorting and classification to provide generality to the process that can be developed into robust new plastic bottle recycling patterns in various recycling operation environments.

Recycling of plastic bottle is indispensable as they are non-biodegradable polymers containing one the environmental deteriorate greenhouse (carbon) and other elements such as hydrogen and chlorine which can react to form a toxic compound that poses danger to the living environment. Rapid increase of the world population has led to an increase in demand of plastics-based commodity. To avert the impending dangers associated with environmental pollution of polymer-based wastes, there is a need for effective recycling program. Initiation of effective recycling program in Melaka will provide employment opportunity, reduce high energy needed for fresh production of plastic bottles, the risk of environmental pollution and reduce landfilling of reproducible and reusable which through recycling can be recovered. Rapid depletion of highly depended fossil fuel and increasing energy demand motivated requires for research on recycling of plastic bottles which are commonly used for food, beverages and industrial chemical storage.

Inert properties of plastic materials makethem an ideal candidate for a number of technological applications. In the present study, a new framework for plastic bottle recycling is proposed basedon AHP. The proposed framework could potentially be used for the classifying of the chemical composition and transparency of the plastic bottle after sorting has been performed. However, this new framework is capable of achieving competitive output value at lower cost compared to the present commercial systems. This will provide an improvementopportunity to enhance the technological operation setting at a reduced cost.

In considering the importance of plastic bottle recycling in Melaka based on the proposed framework, the adoption of plastic bottle recycling practices in Melaka is an important step towards maintaining a healthy environment. From an educational viewpoint, recycling of plastic bottle will provide information on various plastic types of plastic bottles and their chemical composition in Melaka. From the research viewpoint, recycling of plastic bottles will provide job opportunities and enable the control of recyclable material plastics that could amount to large volume when disposed in landfills.

1.5 Scope and Rationale of the Study

The scope of this study focuses on plastic bottle recycling in Melaka, Malaysia and will be based on data that will be collected. In this study, recycling practices will be limited to Melaka. This study will further investigate the main recycling activities, the frequency at which recycling activities are conducted. However, better understanding on how recycling activities are carried out and its relevance to a growing economy is very important because it will reveal opportunities for efficient use of resources.

Recycling of plastic bottles was chosen in the present study because most soft drinks use plastic bottle because it does not rust or react to the content unlike metallic materials. Understanding the how plastic can be efficiently used is crucial and provide a platform that motivates student to effectively learn from alternative resource management options which are needed in the industries. In addition, recycling reduces dumping site space; provide job opportunities and helps in keeping with healthy environment. However, this study will provide a vital step towards achieving a sustainable material use practices (plastic bottles) needed for a developing economy such as Malaysia. Recycling techniques in Melaka were evaluated using

three models which are mechanical recycling model, chemical recycling model and thermal recycling and are favorable recycling techniques in the world. These models were validated using some important criteria such as cost, quality, efficiency and environment and were chosen because of their significant impact on plastic recycling practices.

1.6 Order of the Thesis

The present study focuses on the development of a new framework for the recycling of plastic bottle base on AHP. To evaluate the recycling practices in Melaka, the study is structured as follows:

Chapter 1 introduces the research the context of the study and provides a general view that the present study covers. The chapter further explains the key points that convey the research work and the direction that were used to meet the research objectives

Chapter 2 provides a literature review of previous related study base in the study context. The chapter highlights on the importance of various recycling practices of used plastic bottle products and the compositions.

Chapter 3 presents the methodological approach that will be used for data analysis. The AHP models analysis based on the criteria will be evaluated using quantitative data collected using a survey questionnaire were discussed.

Chapter 4 discusses the analysis and result obtained from field survey base on which recommendation on the sustainable plastic bottles recycling practices in Melaka will be generalized while chapter 5 presents the study's conclusion and recommends recycling practice base on AHP framework.

CHAPTER II

LITERATURE REVIEW

2.0 Introduction

Recycling of used plastic bottle wastes provide opportunities for their reprocessing into a usable form. Plastic bottle disposal accounted for the largest share of total recyclable waste of over 50% of the total waste generated in most countries (Alhumoud et al., 2007). Used plastic bottle contained high energy content. However, the estimation of their environmental impacts when they are incinerated contributes to global warming. Recycling provide alternative means to transform the used plastic bottles in Melaka into a usable through the environmentally sound recycling method. Recycling of plastic bottles in Melaka is a step to establishing a healthy environment. Recycling practices comprises of a sequential hierarchy of solid waste management (Tadesse et al. 2007) and is required to be integrated into the environmental management programs in Melaka.

In order to obtain information on various recycling practices that have been used in previous literature studies, this chapter presents a brief review of related studies on plastic bottle recycling activities, recycling method and approaches that have been used to recover used

plastic bottle. Literature study will provide an array of information that will be used to enhance the proposed new recycling framework of plastic bottles in Melaka.

2.1 The Study Location

Melaka is the smallest state in Malaysia after Perlis and Penang. Based on the information obtained from the GeoNames geographical database, the population of Melaka is about 180671. Melaka is located at 2.196 latitude in degrees, 102.241 longitude in degrees at an altitude of meters. The map of Melaka is shown in Figure 2.1. The state of Melaka has recently been experiencing environmental problem basically from flood resulting from blocked drainage system and raise the sea level (Ninth Malaysia Plan 2006 – 2010). The adoption of a new plastic recycling framework in Melaka will provide an economic alternative to maximize the use of plastic bottles and reduce the rate of their illegal disposal contributing to the blockage of the drain system. The recycling of used plastic bottle should be integrated into waste management initiatives in Melaka. Decision makers, authorities and planners of municipalities are required to enforce laws to facilitate the recycling of used plastic bottles through;

- 1) Establishing policies, legal and strategies to encourage and promote recycling activities.
- 2) Setting up of network of plastic bottle recycling depots and shops where recyclable-junk buyers, used plastic bottle collectors, waste picker could sell their collection
- 3) Subsidizing plastic bottle recycling facilities such as keeping the market price of recyclable plastic bottle wastes, supporting recycling enterprises. These are among the essential steps needed for the development of used plastic bottle separation technique.