Development of the Material Security Database for Malaysia Assisting the Product Recycling Desirability Model

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

by

YOONG QI HANG

B051720045

971206-05-5341

FACULTY OF MANUFACTURING ENGINEERING

2021

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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Tajuk: **DEVELOPMENT OF MATERIAL SECURITY DATABASE FOR MALAYSIA ASSISTING THE PRODUCT RECYCLING DESIRABILITY MODEL.**

Sesi Pengajian: **2020/2021 Semester 1**

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_____ _____

Alamat Tetap:
Lot 8343, Kampung Baru Grisek
Ledang, 84700 Muar,
Johor.

Tarikh: 8/2/2021

Cop Rasmi:

TS DR AL AMIN BIN HJ MOHAMED SULTAN
PENSYARAH KANAN/SENIOR LECTURER
FAKULTI KEJURUTERAAN PEMBUATAN
UNIVERSITI TEKNIKAL MALAYSIA MELAKA
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Author's Name : YOONG QI HANG

Date : 8 Febuary 2021

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:

(Ts. Dr. Al Amin Bin Mohamed Sultan)

ABSTRAK

Pada hari ini, masalah pembaziran bahan adalah isu yang serius di negara yang membangun seperti di Malaysia. Terdapat satu model yang bernama Model Kehendak Kitar Semula Produk dapat meningkatkan kadar kitar semula. Namun begitu, model ini todak dapat digunapakai di Malaysia sebab kekurangan satu unsur, iaitu Index Keselamatan bahan. Satu pangkalan data diperlukan untuk menentukan Index Keselamatan Bahan. Terdapat dua dimensi yang diperlukan untuk membina pangkalan data keselamatan bahan, iaitu risiko bekalan dan risiko bahan. Bagi risiko bekalan, terdapat empat penunjuk, antaranya ialah ketidakcukupan bahan, penawaran monopoli, kestabilan politik, dan kerentanan perubahan iklim. Bagi risiko bahan, antara empat penunjuknya ialah tahap penggunaan di Malaysia, kebolehtukaran, potensi pemanasan global, dan jumlah keperluan bahan. Setiap penunjuk ada cara permakahan tersendiri untuk menilai keselamatan and kritikan bahan. Selepas itu, bahan-bahan yang telah dimarkah plot dalam matrik bahan keselamatan untuk mendapat bahan yang paling kritikal. Dalam projek ini, terdapat 89 bahan telah dikenalpasti sebagai bahan yang kritikal, antara lima bahan yang paling kritikal ialah Paladium, Rodium, Emas, Platinum dan Telurium. Dasar dan inisiatif kitar semula dapat diaplikasikan secara strategis oleh kerajaan, inisiatif ini termasuk implementasi Model Kehendak Kitar Semula Produk dengan mengembangkan pangkalan data keselamatan bahan untuk ekonomi Malaysia.

ABSTRACT

Today, in developing countries like Malaysia, the problem of material waste is a critical concern. There is a recycling model named the Product Recycling Desirability Model was able to boost the recycling rate. However, the model is not applicable to Malaysia because of missing element of material security index. To determine the material security index, a database is needed. There are two dimensions used to develop material security database, which were supply risk and material risk. There are four measures of supply risk, which are scarcity, monopoly supply, political stability and climate change vulnerability. While the four indicators for material risk are Malaysia's consumption levels, substitutability, global warming potential and total material requirements. Each indicator had its own scoring method for evaluating the security and criticality of the material. Then the materials plotted on material security matrix to determine the most critical material. In this project, critical materials had been identified and assessed where 89 materials were classified as a critical for Malaysia with the five top ranked material are Palladium, Rhodium, Gold, Platinum and Tellurium. The outcome of this project was used in the Product Recycling Desirability Model to assess the desirability index for recycling products. By having the material list, the recycling policies and initiatives can be strategically enforced by the government, including the implementation of Product Recycling Desirability Model, by developing the material security database for the Malaysia's economy.

DEDICATION

Only

My beloved father, Yoong Chee Seng

My appreciated mother, Lim Sau Heong

My adored sister and brother, Yoong Li Suen and Yoong Li Yang

For giving me moral support, money, cooperation, encouragement and also understandings

Thank You So much & Love You All Forever

ACKNOWLEDGEMENT

I would like to express my gratitude to several individuals for supporting me to complete my project without difficulty. First, I wish to express my sincere gratitude to my supervisor, Ts. Dr. Al Amin Bin Mohamed Sultan, for his patience, advice and guidance that have helped me to complete the project.

Next, I would like to give a special thanks to my best friends that have give me so much motivation and cooperation in completing this report especially to, Tay Hock Seng for teaching me the way to arrange the sequences of the project. Thanks for the great friendship.

Besides that, I would like to thank my parents that always fully support and encourage me in completing the project.

Finally, my thanks and appreciations go to everybody who was important to this FYP report, as well as expressing my apology that I could not mention personally each one of you.

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

2-D	-	2 Dimension
3-D	-	3 Dimension
3R	-	Reduce, Reuse, Recycle
AHP	-	Assess Analytic Hierarchy Process
CE	-	Circular Economy
CEEW	-	Council on Energy, Environment and Water
DOE	-	Department of Energy Malaysia
Dy	-	Dysprosium
E&E	-	Electric and Electronics
ELVs	-	End of Life Vehicles
EU	-	European Union
E-waste	-	Electronic Waste
GDP	-	Gross Domestic Product
HDD	-	Hard Disk Drive
IPI	-	Industrial Production Index
JMG	-	Jabatan Mineral dan Geosains Malaysia
LCA	-	Life Cycle Assessment
LCD	-	Liquid Crystal Display
LIBs	-	Lithium-Ion Batteries
MSI	-	Material Security Index

NASA	-	National Aeronautics and Space Administration
Nd	-	Neodymium
PCB	-	Printed Circuit Board
PGM	-	Platinum-Group Metals
Pr	-	Praseodymium
R&D	-	Research and Development
RDI	-	Recycling Desirability Index
REE	-	Rare Earth Element
RPA	-	Recycling Potential Assessment
TMR	-	Total Material Requirements
TRL	-	Technology Readiness Level
UK	-	United Kingdom
US	-	United States
USA	-	United States of America
WEE	-	Waste Electric and Electronic Equipment

LIST OF SYMBOLS

%	-	Percentage
Kg	-	Kilogram
pH	-	potential of Hydrogen
RM	-	Ringgit Malaysia
USD	-	United States Dollar
Tons	-	Unit of measure weight, tonne

CHAPTER 1
INTRODUCTION

1.1 Background

Nowadays, the material wastes problem is a serious issue in developing countries such as Malaysia. The reason for this issue is the value of end-of-life products are not given more attention. Most of the products were send to landfill in its end-of-life. So, recycling is very important step to overcome this wastes problem. Recycling can reduce the need for extracting and refining virgin raw materials by recycled the useable materials from end-of-life products, at the same time can reduce the amounts of end-of-life products dumped into landfill. Therefore, it is necessary for Malaysia to have a measure or method to assess the importance of the products for recycling based on the country's economy.

Material security, also known as material criticality is the concept of evaluation on certain material based on different factors. The factors can be geological deposit, social issues, recycling potential, regulatory structure, environmental issues and sustainability (Graedel & Nuss, 2014). So, the material security can be defined as a strategy to determine a material criticality and evaluate the material from varies parameters and indicators. The material security also expressed as material scarcity or resource efficiency (Hollins, 2008). The factors and indicators of assessment of material security is determined by the scope of research. However, there is no perfect or constant factors or indicators for the assessment of material security. The material security plays a key role in material selection, product design, material recycling decision, as well as in investment decision. The result of the criticality

assessment is to obtain the list of critical material and the list of critical material is useful to identify and prioritize materials concern (Fortier et al., 2018).

Recently the worldwide market for semiconductor industries is growing at 15% per year. This phenomenon causes the semiconductor industry has been one of the most important sectors for economy growth (Izumi, 2004). Most of the raw material that used in semiconductor manufacturing is included in the list of material security. However, the production of these raw material include REE's is concentrated and monopolised by small number of countries only. This situation has triggered the manufacturer to find a solution to sustain the supply of these raw material (European Commission, 2014). One of the solutions is recycled the old electronic product and extracted the useable material, such as gold, copper, nickel, indium etc. There are studies that introduced some recycling model, while in this research the model referenced is Product Recycling Desirability Model.

The concept of material security can be used to develop the Product Recycling Desirability Model (PRDM) (Sultan et al., 2017) . This model can identify the highly desirable product for recycling and strategically prioritise them based on three critical factors that had been assessed by the study in the UK and was successfully applied to several cases in US, EU, India and China. Moreover, the material security plays a key role in material selection, product design, material recycling decision, as well as in investment decision. The concept of material security also able to sustain the economy, reduce the environmental issues, reduce the manufacturing cost, and prevent shortage of material in future demand (Speirs & Gross, 2013). This is because thee assessment of material security is useful to monitor the consumption pattern of a mineral across the industrial sectors and contribution of the material to overall economy (Gupta et al., 2016).

In the 21st century, the global raw material demand patterns were remodelled due to the developing lifestyles, development of new technologies, market dynamics and government policies (Erdmann & Graedel, 2011). The assessment of material security could be conducted by different methodologies. A variety of dimension and factors can be chosen to conduct the assessment of material security. The assessment's dimensions can be supply

risk, impact of supply restriction, economic importance, recycling, political factors, environmental implications etc.

The concept of material security is a matter of concern for the global economy. In order to determine the critical material, also known as insecure material, a framework was developed by Erdmann and Graedel (2011). There are two main dimension that used to determine the critical material, which are material risk and supply risk. For the material risk criteria contain global consumption level, lack of substitutability, global warming potential and total material requirement. While for supply criteria contains scarcity, monopoly supply, political instability, and vulnerability to the effects of climate change (Hollins, 2008). The list of critical material can be used as guideline for recycling process. The supply risk dimension goes beyond output concentration and takes into account other considerations, such as substitutability and recyclability. If a material has high functional substitutability, then it can lower its risks (Gupta et al., 2016).

There are several countries have start to conduct the studies on assessment of material security such as EU UK, U.S, India and Japan (Devauze, 2017; Hollins, 2008; Fortier et al., 2018; Gupta et al., 2016; Hatayama & Tahara, 2015). In EU, the criticality of material is used to strengthen the industrial competitiveness by implement the EU industrial policy. This can increase the overall competitiveness of the EU economy. With the list of critical of material, it can use to help prioritise needs and actions. Furthermore, it can help to promote the European production of critical raw materials and encourage the launching of new mining and recycling activities (Devauze, 2017). In UK, the material security is conducted to develop the recycle desirability model. This model can identify the highly desirable product for recycling. In other words, it can develop a model that can prioritising recycling of end-of-life products in a circular economy(Mohamed Sultan et al., 2017) .

In India, material security is conducted to solve the two main problems, which is lack of suitable technology adoption and inefficiency policy mechanism to drive mining and exploration. A mineral or material will restrict when there are sudden supply shocks in the supply chain, it can be more serious when there are no substitutes available in specific

applications. The benefit for the study about the criticality of material is offered policy makers a detailed analysis on the determinants of criticality associated with minerals and the economic importance of minerals (Gupta et al., 2016).

In Malaysia, the main contributor for Malaysia economy is manufacturing industry. However, the growth of manufacturing industry especially E&E industry has created varies challenges to manufacturer, such as increase the consumption level of raw material and cause some rare materials became scare and the end-of-life product is not utilized properly. This situation can influence the recycling rate in Malaysia. In Malaysia, the recycling rate of electric and electronic products and automotive products are relatively low, the overall recycling rate in 2015 is only 10.5% and estimate in 2020 the recycling rate can increase to 22% (PEMANDU, 2015). While recycling rate in Singapore has 60.6% in 2015 (European Environmental Bureau & Eunomia, 2017). So, it is important for Malaysia to develop a strategy that can help manufacturing companies especially E&E and automotive sectors to achieve sustainability in their production and increase material efficiency.

There are a few reasons that trigger the conducting of material criticality assessments. It includes the increasing and new demand for materials from developing economies, demand for wider range of materials inputs from new technologies, concentrations of production, creating supply monopoly and recognition of the social and environmental consequences of mining. The list of critical material can use to make recommendations and suggestion for mitigating actions, including the need for investigation and policies to reduce future supply restrictions (Lloyd et al., 2012).

There are several determinants that needed in assessing supply risk. There are five main determinants that listed in many reports, which is geological, technical, political, environmental and social, and economic (Lloyd et al., 2012). The geological, technological and economic element is comprised of two equally weighted indicator, one is examines the relative abundance of the metal and the other is percentage of the metal mined as a companion (Graedel et al., 2012). For the environmental and social indicators, the two indicators can influence and inhibit the primary production. Environmental factor is more

likely to restrict material supply than physical scarcity. For example, international and national laws curbing greenhouse gas emissions may come to restrict the more carbon-intensive extraction processes required for a range of minerals. In the Hollins (2008), it was used two proxies for environmental impacts, which are global warming potential and total material requirement. The assessment in determine critical material can affect by the future demand as well. Future demand is the key determinant of its future availability. There are two factors that used in criticality assessment, which are future demand projections and substitutability (Speirs & Gross, 2013). Normally a material that listed in critical material list has low mining rate and recycling rate, so it should improve its resource efficiency to prevent restriction of the material.

1.2 Problem Statement

In year 2020, Malaysia's industrial production index (IPI) had grown up by 0.6 percent. The growth of the IPI was driven by the increase in the index of manufacturing. The major sectors that contribute the rise of index of manufacturing was non-metallic mineral, basic metal and fabricated metal products. The information shows that the capacity of used of raw material is increasing and this may cause the restriction of material.

A strategic decision-making tool is a necessity to identify the important materials and products towards prioritising end-of-life waste for recycling. Product Recycling Desirability Model is one of the tools that successfully developed and applied to the UK, US, China, and India. However, the model is not applicable to Malaysia yet because the missing parameter and dimension that also known as material security index for Malaysia. This also led to the missing opportunity for the government to strategically plan the recycling initiatives by considering the importance materials based on Malaysian economy. Hence, the development of material security can be one of the parameters of the model and it may help to assist in increasing the recycling initiatives in Malaysia. The second consequence is the hardship to assess the scarce material's quantity that cause restriction for the usage of those

materials. If a certain material usage is suddenly increasing, it will cause the restriction of material and increase the cost of material. The condition is getting serious when the mining of the material is monopolized by some countries. When the material cost is increase, the production cost will rise too. Hence, with the list of security material, consumer can reduce the demand of the material or use the material more efficiency.

There are some dimension and factors needed to conduct the assessment. The assessment needs to analyse the impact of materials and industrial in Malaysia. From that analysis, suitable criteria will find for develop the material security list and material security index for Malaysia.

1.3 Objective

The objectives of this study are:

a) To identify the critical material for Malaysian economy.
b) To model the important parameters for the critical materials
c) To assess the material security of the critical material.
d) To apply the product recycling desirability model for assessing the criticality of material for Malaysia.

1.4 Scope

This study is helps in determine the criticality of material for Malaysia. The case and scenario of the critical material study is based on the importance of Malaysia economy, and efficiency of raw material. The reason that selects the two elements is because contribution