

End-of-life Metal Recycling Desirability (MRD) model using critical factors integration for sustainability

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ABSTRACT – The amount of end-of-life waste is increasing and traditionally would be disposed of in the landfill. There is a limited scientific model or measure to oversee the issue. Therefore, this paper identifies the critical factors for recycling from the metal manufacturing company's perspectives. The factors were formulated into a score using the mathematical approach. The volume of material in a product and the current recycling performance were integrated into the existing model to introduce a metal recycling desirability index. This model is applicable for the wide range of the end-of-life products recycling assessment and it would act as a strategic indicator to assist the companies, stakeholders or governing bodies to boost the recycling rates, locally and globally.

1. INTRODUCTION

An increase in global manufacturing activities is evident. Globalization, industrialization, and economic development has led to an increase in product demand and increased manufacturing activity, which saw a 35% increase of global manufacturing activities in ten years while the global GDP increased by 26% [1], also lead to larger volumes of industrial (material) waste [2]. For industrial waste management in Malaysia greater priority is given to end of pipe approaches than waste minimization and recycling. Rampant evidence of illegal waste disposal and lack of land implies the inefficiency of industrial waste management methods. The waste such as the end-of-life product manufactured by the company can be turned into useful material by recycling. A company to recycle the product, they need to sort out the most to the least priority type of material to be recycled to be operating at the minimal cost and energy consumptions.

By figuring the ideal factors to prioritize the material before recycling, the importance of the material to be recycled can be determined. This research needs data from industries to get accurate results, but as the data are private and confidential, it takes a long time to acquire it. With limited model in-place it makes hard for the industrial company to be prepared for the future crisis that may hold or cut the global supply chain, as an example, limited natural resources, political instability or the recent evidence when the world was impacted by the virus of COVID19. The global supply chain was impacted with the supply cut including for the Personal Protective Equipment and important medical appliances. Apart from this, the pollution, damaged ecosystem,

global warming and ocean acidification are getting more severe which could be indirectly assisted by strategic recycling initiatives.

As the waste is increasing at a fast rate in this modern era, the landfills are also predicted to be used up in the future because of the limited land in this country. Besides, manufacturing is one of the biggest factors that generated waste, thus, recycling of waste is very essential. The industrial company requires as a guide to finding out the material that should be prioritized when the company would start recycling in the company.

The previous researcher had identified the What Gets Recycling model [3] and Product Recycling Desirability for different kind of products and it was successfully applied at international levels such as for the United Kingdom, European Union, and India [4]. However, this model is not yet applicable for developing countries such as Malaysia as the material security measure which developed based on the importance for the Malaysian economy is yet to be explored. Besides, the application of the model at the manufacturing firms' level is limited. The critical factors that suit the companies may differ considering the local atmosphere in comparison to what had been reported. Thus, by taking a metal manufacturing company as an example, the real application of the suitable model at the local context would be examined.

2. METHODOLOGY

The important parameters were identified through the literature finding and later verified by the industrial player. The parameters then were transformed into an integrated score using the formulas that were referred from the previous work and also developed based on the newly identified factors. The existing measures such as the simplicity of material separation and the recycling technology readiness were obtained from the Product Recycling Desirability Model [4]. Those measures were integrated with the new measures that were developed in this study. The new measures were the material volume index as in Equation (1) and, metal recycling index as in Equation (2), with Cr co-efficient, = 238. This integrated new model was applied to the five metallic products in a company (i.e. Bracket LS 600, Bracket U1 600, Bracket ZL-600, Door Holder 1224 and Electromagnetic Doors-600 LED) and the most desirable products for recycling were identified. This model also was compared to the previous model.

$$D_{Volume} = \sum_{n=1}^M \left(\frac{M_i P_i}{MT P_{top}} \right) \quad (1)$$

$$D_{Recycling} = \frac{\sum S}{Cr=238} \quad (2)$$

3. RESULT AND DISCUSSION

The metal recycling desirability (MRD) index is considered highly worthwhile for recycling when the index is higher in comparison among the selected products for recycling in the research with the top index value is three. This is consistent with the previous model. The metal desirability model considering the highest index value in this research can be referred to Figure 1. The most desirable metal-based-product to be recycled in the selected company is Bracket ZL-600 (2.6683). This is followed by Bracket LS-600 (2.521), Electromagnetic Door (2.1258), Bracket U1-600 (2.0401) and Door Holder (Square) 1224 (1.8416). The Bracket ZL-600 has the highest composition of aluminium compared to others, obtained the lowest recycling index as it only consists of two recyclable metals (i.e. steel and aluminium). The simplicity index of the product is also high as it consisted of four materials compared to the electromagnetic door and door holder. The least desirable product for recycling is Door Holder 1224. This product has the second low index for volume and simplicity compared to other products but obtained the higher composition of material from the most products except for electromagnetic lock-600LED (simplicity index) and Bracket U1-600 (volume index).

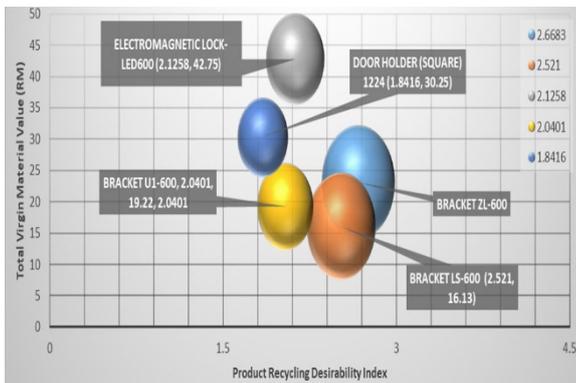


Figure 1 Metal-Recycling Desirability Model

The recycling metal recycling desirability model also has been compared with the previous model [4] and the result is shown in Figure 2. Based on the previous model, the popular product for recycling was BRACKET LS-600 (1.0000) as it has less complexity of material properties. While the least desirable product is the electromagnetic lock (0.225) as it is the most complex product. The previous model only considered the single material separation factor only while the metal recycling desirability is more specific with the additional important factors for the company and this could improve the reliability of the model and the

decision in selecting a main product or waste for recycling.

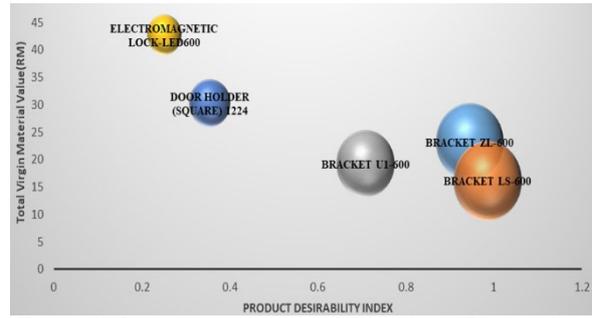


Figure 2 Comparison with the Recycling Desirability Model

4. CONCLUSIONS

The novel of this research would be the determination of the critical factors such as recycling index and volume index based on the stakeholders' importance in addition to recycling technology readiness and material simplicity index that were identified in the previous studies. Through this research, the additional new factors namely Metal Recycling Desirability Index was introduced and strengthened the existing model. This will widen the future research possibilities for further analysis regarding the study of recycling and the other potential applications of the new model in the local metal industries. This could be a starting guide for the companies and as an early step, the company could focus strategically when they want to initiate the recycling activities. Once implemented, this would be a kick start for other companies to replicate and apply the finding based on their needs. It is the aspiration that the selected company possibly could save the time, money, energy and operate at environmentally sound by adopting this method.

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