E-RECYCLING SYSTEM MODEL AND ITS APPLICATIONS TO PLASTIC, PAPER AND DISC

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ABSTRACT

Lately, Malaysians tend to generate wastes at an alarming rate, for instance; discs, paper and plastics. Abreast of that, the conventional recycling systems that have been constructed in Malaysia typically are not widely marketed and are lacking of practical applications. This study comes with an intention of concentrating on the improvement of this particular conventional renewed E-recycling system model that includes database system (generally known as Merit Point Incentive (MPI) system) and CAD model. Due to its applicability, the model is examined by Linear Static and Fatigue analyses. The comparison (cost efficiency) amongst the conventional and E- recycling systems are shown throughout this study.

Keywords: *Conventional system, E-recycling system, MPI system, CAD model.*

1.0 INTRODUCTION

Nowadays, solid waste management continues to be viewed as a serious topic for Malaysian government. Effect of the alarming rate of waste generated due to the grow in population, affluence and changing lifestyles in Malaysia, the environmental restrictions seem to have been encountered which included the stringent influence over waste disposal sites, resource restrictions, for instance; emphasizing the awareness of the public about the depletion of resources naturally, the natural disasters' issues such as global warming that caused by the green house effect. In other perspectives, the improper waste management will face serious biohazards, occasionally; it might even cause death. These issues are generally addressed as the roadblock toward the government's efforts to attain sustainable development approach vision 2020.

Ros (2009) explained that the overall solid waste generated per day is 18000 tones in Malaysia; sadly most of the wastes generated are dumped illegally and disposed in landfills (Figure 1). Consequently, waste management is a vital issue that needs the effectual solutions and recycling is always viewed as a crucial aspect of an effective and efficient solid waste management system. Billatos and Basaly (1997) said that recycling is the reuse of products in the same capacity for which they were originally manufactured. While Tchobanoglous *et al*., (1993) discussed that recycling involves three main steps, those are (1) the separation and collection of waste materials, (2) the preparation of these materials for reuse, reprocessing and remanufacture and finally (3) the reuse, reprocessing and remanufacture these materials (Figure 2). In addition, processing plays an important role in improving the quality of recycling system (Tchobanoglous *et al*., 1993; Anderson and Bordin, 2005; Chenayah *et al*., 2007). In this study, three recyclable materials are mostly concerned to explore such as discs, paper and plastics. Kosior *et al*., (1997) found that 10 % of the produced discs are rejected and disposed in landfills. Discs contain the non-biodegradable polycarbonate, heavy metals and harmful dyes which lead to the serious pollution problems while for the waste papers such as old newspaper, cardboard, high-grade paper and mixed paper (Tchobanoglous *et al*., 1993) as well as in plastics have seven families that can be recycled (Table 1) as mentioned by (Vesilind *et al*., 2002).

Presently, there is only the existing of the conventional (manual) recycling system for the above materials whereas not for the developed system in this study. For the system's uniqueness, Merit Point Incentive (MIP) system has been fully engaged to encourage the public use this E-recycling system efficiently. The outlines of this study mainly consist of introduction, followed by the development of E-recycling system model, continued with result and discussion and finally conclusion and the related suggestions for future work.

Figure 1: Almost all landfills in Malaysia are open dumps that have no pollution control measures (Tan, 2004).

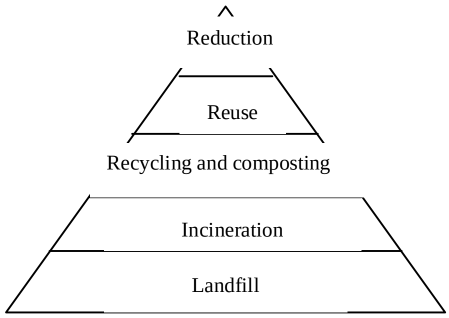


Figure 2: Hierarchy of the integrated solid waste management (Heimlich *et al*., 2009).

Table 1: Seven plastic families (Vesilind *et al*., 2002)

Code System	Chemical Name	Abbreviation
01 PET	Polyethylene Terephthalate	PET / PETE
02 PE-HD	High-Density Polyethylene	HDPE
03 PVC	Polyvinyl Chloride	PVC
04 PE-LD	Low-Density Polyethylene	LDPE
05 PP	Polypropylene	PP
06 PS	Polystyrene	PS
07 O	Mixed Plastic	O

2.0 DEVELOPMENT OF E-RECYCLING SYSTEM MODEL

2.1 MPI System

With purpose to activate the MPI system, recycler will be asked to enter his/her username and password. In this system, notepad (text file) has been used as a database to store the login details of the recyclers. The system will then identify whether the recycler is registered or vice versa. If the recycler is registered, the system will display "found" and recycler will be asked to throw the recyclable materials into the recycle bin. Else, if the recycler is unregistered, the system will display "not found". In order to use MPI system, he/she has to create a username and password which are very simple and convenience. After that, recycler will be inquired to throw his/her recyclable materials into the recycle bin. The weight of the recyclable material thrown and the total points that are merited will be displayed on the screen. The MPI will be standardized where no matter which types of recyclable materials either discs, plastics or papers. Recyclers will be merited with the points in accordance to its weight. To simplify this system, the implementation of recycler cards is eliminated.

The recycler will then get the printed receipt that stated the total points he/she earned. This receipt can be used to exchange the cash from the government (or in related agencies). Figure 3 shows the process flow diagram for the developing of MPI system using C++ language programming.

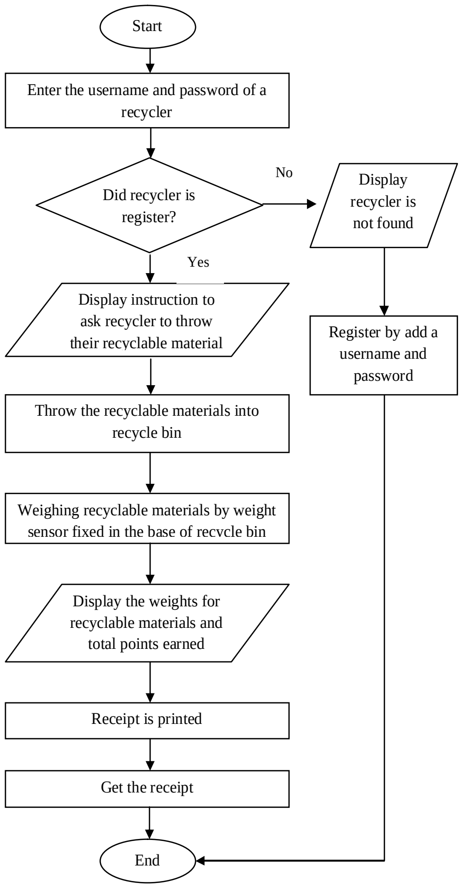


Figure 3: Process flow diagram in MPI system.

2.2 E-recycling CAD Model

In reference to Concept Design and Selection (CDS), the model may consist of recycle bin, weight's evaluation, disc separator, paper and plastic separator, pipelines, storage tanks, docking station and pneumatic refuse collection system (Figure 4). For its procedure, the recyclable materials (discs, paper and plastics) are thrown into the recycle bin where the evaluation of weight for these materials will be generated throughout the weigh sensor that is fixed at the bottom of the recycle bin.

Hence, a door on the bottom of the recycle bin will open and the recyclable materials will drop into the pipeline and go through the disc separator. There are eight sets of blades (with the gaps) in the disc separator that only allow the disc's size. The discs are then separated from the waste stream and dropped into the gap between the blades (with the constant rotating motion), and strictly stored in the tanks. Pneumatic refuse collection system is used to collect the discs through the docking station. The procedures remain the same as for the papers and plastics. The following figure depicts the E-recycling CAD model using CDS and the tool, Solidworks. The explorations of the resulting of MPI system and this CAD model analysis are completely explained in the next section.

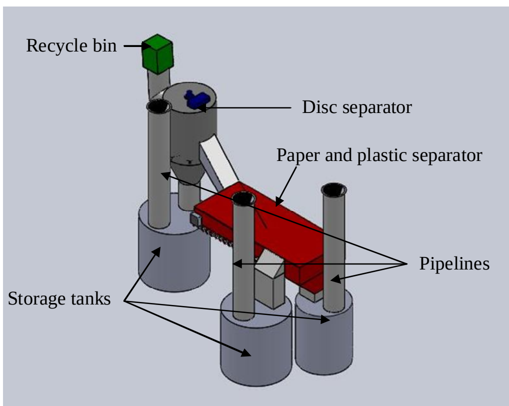
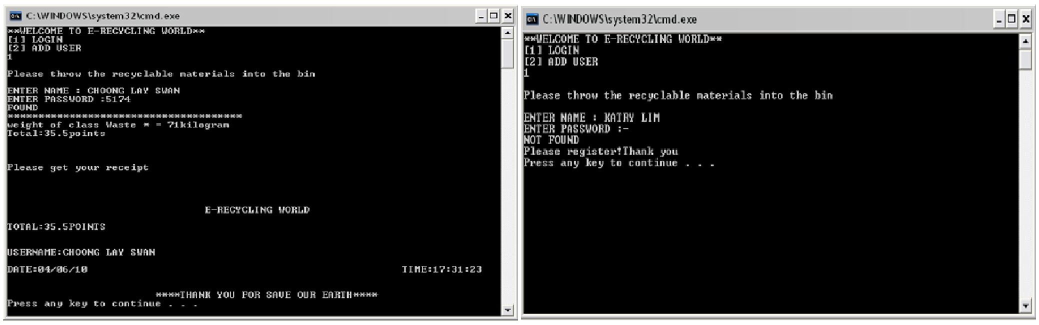


Figure 4: E-recycling CAD model.

3.0 RESULTS AND DISCUSSION

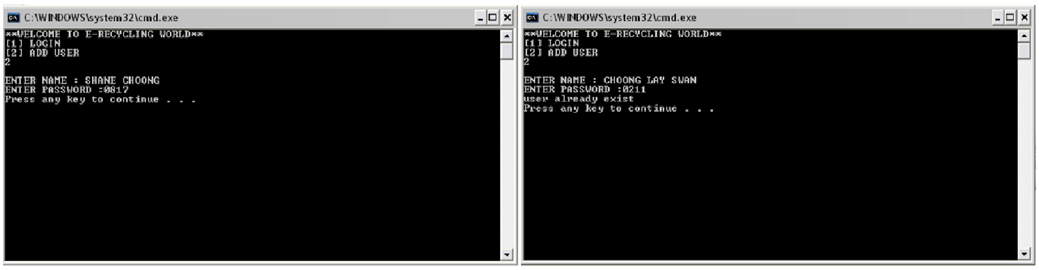
3.1 Resulting of MPI System

In this MPI system, weight of the recyclable materials will certainly be automatically generated, and it actually has been standardized for all sort of recyclable materials. Basically, the system comprises two parts, which are the registered user login and add user (still not registered). As a way to keep the login details on the users, text file is utilized as the database where when the new username and password are added, it will be automatically updated. In addition, it will also automatically detect for the username that has been used and the user must use other usernames except the existing name. The following figures are the outputs of the C++ programming in MPI system.



(a) **(b)**

Figure 5: Output with the **(a)** registered, **(b)** unregistered users.



(a) **(b)**

Figure 6: Output with the **(a)** add-on new, **(b)** existing users.

The main purpose of MPI system is to incentivize the users who consistently use this recycling system. Besides, in response to simplify the merit point system, the receipt printing concepts are applied. This is due to the implementation of recycler card will reduce the percentage of publics to recycle. As it is a difficult task for the public to apply and become a recycler card holder. The printed receipt can be used to exchange the cash or the related token from the government such as Majlis Perbandaran Pulau Pinang (MPPP) or in the post office. Apart from that, MPI system is also used to eliminate the middleman. Henceforth, the win-win system needs to be considered. Suppose the recyclable materials are RM 1.00/kg. If publics sell the recyclable materials to the middleman, they will be paid within the rate of RM 0.20/kg.

At the same time, the middleman will be paid with RM 1.00/kg by selling the collected recyclable materials to the recycle centers. In this situation, if the middleman is eliminated, publics and government will be benefited in this win-win situation, where publics can be paid RM 0.50/kg that is RM 0.30/kg more than what the middleman gives to them. While for the government, may save RM 0.50/kg from paying to the public directly and not through the middleman. It is unnecessary to create a database system to keep the details of the users since the concept based on “bonus link” is implemented.

3.2 Storage Tank Model Analyses

Due to the structural efficacy, storage tank (Figure 7) is investigated through Linear Static and Fatigue Analyses. Both analyses are frequently applied in physical structures, for instance; stress, force and displacement distributions (Yahaya *et al*., 2012). Finite Element Analysis (FEA) is the most common tools for the analysis while Stainless Steel Grade 304 (AISI 304) is chosen for the selection of material in this study. The characteristics of AISI 304 are depicted in Table 2.

Besides, the mesh generation info of this model is also shown in Table 3. Boundary Conditions (BC) are placed on the two surfaces of the storage tank due to the Forces (*F* or also referred to as a loading condition) that might be influenced to these surfaces. These *F* are occurred generally if the recyclable materials are contained in the storage tank.

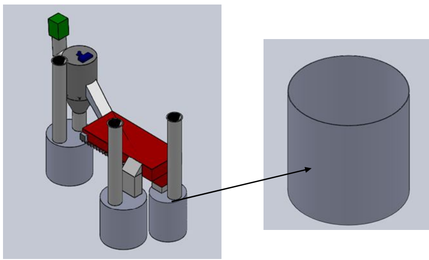


Figure 7: Storage tank model (right) that will be analyzed.

Table 2: Characteristics of AISI 304

Modulus of Elasticity	Yield Strength	Ultimate Strength	Poisson Ratio	Density	Damping Coefficient
190 GPa	206.81 MPa	505 MPa	0.29	8 gcc^{-1}	0.003

Table 3: Mesh data structure

Mesh Type	Solid Mesh
Mesher Tool	Standard
Automatic Transition	Off
Smooth Surface	On
Jacobian Check	4 points
Element Size	50.008 mm
Tolerance	2.5004 mm
Quality	High
Number of Elements	30893
Number of Nodes	62117
Time to Complete Mesh	56 s

3.2.1 Simulation results and its safety factor

The discussion begins with the presentation of the generated results using Linear Static Analysis. Table 4 shows the maximum Von Mises stress (υ_{max}) distributions in the model throughout the repeated loads, *F*. Hence, the safety factor (S_f) or also known as a design margin (Michalopoulos and Babka, 2000) can be derived using Eq. (1) (Clifford *et al*., 2008; Shenoy, 2004) and where the yield strength of AISI 304 is able to be found in Table 2.

$$S_f = \frac{Yield\ Strength\ of\ \ AISI\ 304}{\upsilon_{max}} \tag{1}$$

Table 4: Result distributions of υ_{max} and S_f in the applied model

F (kN)	υ_{max} (MPa)	S_f
5.00E05	34.7059	5.95893
10.0E05	69.4118	2.97946
15.0E05	104.118	1.98630
20.0E05	138.824	1.48973
25.0E05	173.529	1.19179
29.0E05	201.294	1.02740
29.4E05	203.421	1.01644
29.5E05	204.765	1.00999
29.6E05	204.805	1.00977
29.7E05	205.497	1.00637
29.8E05	206.847	1.00300
29.9E05	206.881	0.99964
30.0E05	208.235	0.99316

Table 4 depicts the presented values of υ_{max} and S_f using the repeated *F*. Failure mode occurs if and only if $S_f < 1$ or S_f has the negative sign (Michalopoulos and Babka, 2000). Thus, the model in Table 4 is safe to be utilized if $F <$ 29.9E05 kN whereas the model is in failure mode if $F \geq$ 29.9E05 kN. These inequalities prove that the model structure is identical for $F <$ 29.9E05 kN while is otherwise if *F* contradicted previously. The findings in Table 4 will surely be employed to predict when the failure (fatigue) modes may start to occur in the storage model. This fatigue prediction will be discussed in the next section.

3.2.2 Fatigue predictor using first-order newton interpolating polynomial

In reference to the failure mode above, let assume that the fatigue starts to occur if $S_f = 1$. Due to this S_f, the related load will be predicted using the first-order Newton interpolating polynomial. The general form of this polynomial such as (Chapra and Canale, 2010)

$$f_1(x) = b_0 + b_1(x - x_0) \quad (2)$$

with

$$b_0 = f(x_0); b_1 = f[x_1, x_0] \quad (3)$$

We can see clearly in Table 4 that the fatigue of the model starts to occur in the range of F [29.8E05, 29.9E05] that allows only two data points. Let do the assumptions where F is denoted as x-axis whereas S_f symbolizes $f(x)$ or y-axis. The algorithm includes four steps such as: Set x_0, x_1, $f(x_0)$ and $f(x_1)$; Calculate b_0 and b_1 using Eq. (3); Substitute x_0, b_0 and b_1 into Eq. (2); Solve x for $f_1(x) = 1$. Finally, the estimated value approximates 29.8893E05 kN. It shows that the storage tank model (Figure 7) is in safety mode if $F < 29.8893\text{E}05$ kN while the fatigue may start occurring when $F \geq 29.8893\text{E}05$ kN. Further discussion about the cost efficiency will be explained in the following section.

4.0 Cost Efficiency

An approach upon the cost-efficiency of recycling is carried out on the conventional and E-recycling system models. This technique can indicate the feasibility of a project or plan by quantifying its costs (Kumar *et al*., 2010). The net operating cost of recycling activities is expressed as,

$$Net\ Cost = Collection\ Cost + Transportation\ Cost + Processing\ Cost - End\ Use\ Material\ Value \quad (4)$$

There are a few assumptions ought to be made typically the processing cost is equal to RM350 per ton; labor cost equivalents to RM350 per ton; transportation cost is RM 70 per ton; recovered recyclable materials sale cost is estimated as RM350 per ton as well as total waste generated is 100,000 tons per year and the recovered recyclable materials almost 40,000 tons per year. By applying Eq. (4), the net cost of conventional approximates to RM140,000,000 while for the cost of E-recycling system is nearly to RM63,000,000. This estimation represents that E-recycling system operates more efficiently than the conventional system. Both systems have the difference approximately RM77,000,000. Thus, the calculation of efficiency is shown as in Eq. (5) (Khai *et al*., 2007). After applying this equation, cost efficiency for E-recycling system approaches to 55% of the saving effectiveness. Therefore, this proposed system can be concluded clearly as the acceptable and relevant system regarding the cost-saving and convenient to use.

$$Cost\ Efficiency = \left(\frac{Output}{Input} = \frac{x_a}{x_t}\right) \times 100\% \quad (5)$$

5.0 Conclusion and Future Work

This study has presented an E-recycling system model that involves MPI system and CAD model. MPI system is introduced to encourage the users to use this E-recycling system. Currently, this E-system is developed particularly wastes such as plastic, paper and disc. CAD model is designed for the simulation purpose using Linear Static and Fatigue Analyses. As a result, the storage tank design remains the same structural (in safety mode) if $F < 29.8893\text{E}05$ kN. Resulting from its cost efficiency, the developed system has 55% of the cost-saving when compare to the conventional system approach. In future, CAD model will be improved which ideal in all fields such as households, industries and towns. In addition, the prototype of an E-recycling system model may build. Apart from that, it is equally suggested to construct the prototype model with full-size and fully functional that will be used to demonstrate the practicality of this developed system.

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