# Managing E-Waste Using the Symbiosis Perspective

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***Abstract*— The production of electrical and electronic equipment (EEE) specifically mobile devices is one of the fastest growing global manufacturing activities. This development has resulted in an increase of waste electric and electronic equipment (WEEE). Rapid economic growth, coupled with urbanization and growing demand for consumer goods, has increased both the consumption of EEE and the production of WEEE, which can be a source of hazardous wastes that pose a risk to the environment and to sustainable economic growth. WEEE includes discarded electronic and electrical equipment. Managing WEEE typically is complex and requires a structured disposal method. However, the process of disposal WEEE sustainably started with a proper sorting and separating from the source, therefore the consumers are under assumption should be aware of the WEEE disposal method. The paper has found consumers are required to have higher awareness level and this awareness level is influenced by two situational factors which are engagement process and supporting facilities and consumer's knowledge on the WEEE itself. Both situational and personal factors are concomitantly necessary to improve the recapturing of WEEE back into the supply chain. This phenomenon is considered symbiotic whereby both factors are equally important in order to acquire sustainability in improving the backwards movement in the logistics. Findings should inform WEEE recycling and disposal system (WRDS) design by municipalities looking to more effectively manage municipal solid waste (MSW) and enhance e-recycling and sustainability. MSW practitioners should introduce systems to support recovery of MSW in sympathy with communication and education initiatives to affect E-good recyclers and should also appreciate a symbiosis effect in the design of WRDSs.**

***Keywords*—** *e-waste, symbiosis, situational factors, personal factors*

## 1. Introduction

The international boom in technological innovation has propelled the global electronics industry to become the largest manufacturing industry in the world. With the massive growth seen in the past 25 years, the concurrent rapid product obsolescence has resulted in a dramatic rise of electronic waste (or e-waste) streams in industrialized countries. E-waste may be described as waste electrical and electronic equipment, in whole or in part from their manufacturing and repair process, which are intended for disposal [1].

The production of electronics is the world's largest and fastest growing manufacturing industry, with the most rapidly expanding stream of waste in the industrial world [2]. Electronic waste (e-waste) includes discarded computers, televisions, cell phones, MP3 players, for the purpose of this research project batteries and cell phones, as well as other forms of electronic appliances considered obsolete, broken or in need of replacement [2], 2011). E- Waste is of environmental and human health concern due to the high composition of heavy metals, plastics, chlorofluorocarbons, flame- retardants, and other hazardous compounds [2]-[3]. Examinations of soil, water, and air in the vicinity of waste management facilities which handle e-waste have demonstrated extreme cases of harmful pollution including heavy metal contamination and the release of toxic chemicals in the form of persistent organic compounds and polychlorinated biphenyls (PCBs) [4].

Consumers desire new products with the latest features. Even though an existing product performed well, electronic equipment was replaced at an alarming rate. The electronics industry thrived on planned obsolescence and as an example, the average computer was only 2 years old [5]. Many corporations have targeted a certain percentage of equipment replacement yearly. Numerous companies have provided for a complete replacement strategy within four years of all computer systems. The amount of electronic waste

***International Journal of Supply Chain Management***
IJSCM, ISSN: 2050-7399 (Online), 2051-3771 (Print)

due to the replacement of obsolete or unwanted electronics continues to rise. Electronic waste has become a global problem affecting both developed and undeveloped countries. Within the United States, e-waste recycling efforts are minimal.

The labour costs associated with recycling electronics are more than the value of the removed components [6]. Due to the hazardous character of e-waste, dumping in landfills is no longer an option. Local, state and national governments have passed regulations restricting or outlawing e-waste in landfills. Restrictions on where to place unwanted electronic refuse have given rise to other outlets of disposal. As the world’s largest producer of e-waste, the United States opposed the United Nations Basel Convention banning the export of electronic waste to undeveloped countries [7]. In order to mitigate the e-waste refuses effectively; it has to be done from the source (point of consumption) [8]. The consumers have to acknowledge their accountability and action of handling the e-waste [8] and the local authority (or municipality) has to come up with a sustainable solution for e-waste recycling disposal system [9].

## 2. Literature Reviews

E-waste as defined in Khan [10], stated that electronic waste or e-waste is electrical and electronic gear disposed of because of out of request, end of life or because of projection of cutting edge forms of electrical or electronic gadgets. The Environmental Protection Agency (EPA) refers to electronic waste as electronic products that are discarded by consumers. Many recycling disposal strategies had been utilized to mitigate e-waste from landfilled, however, the repercussions to the environment still at alarming rate [11].

### 2.1. WEEE Management

As the consumption of electronics products has increased the management of the new type of waste, electronics waste (e- waste, WEEE), has become a global concern. While according to Tanskanen, e-waste contains numerous recyclable materials, for example, ferrous metals and aluminum, copper and valuable metals and additionally distinctive designing plastics [12].

E-waste management is really important to ensure the sustainable development in developed and developing countries [1]. Bilen [13], in his study, found students have insufficient information. The insufficient information is due to a very limited awareness programs from local authorities in promoting sustainable disposal of WEEE [3]. WEEE recycling and disposal system (WRDS) are accountable by local authorities or municipalities for the specified municipal areas [14]. Both WRDS and municipality solid waste (MSW) are reverse logistics from the point of consumption back to the point of origin in capturing back the value of the waste [8].

In supply chain management (SCM), forward logistics is a basic conventional supply chain movement from the supplier over to the manufacturer and the retailer to the consumer [15] however; the backward logistics is an opposite of the conventional flow in supply chain whereby it is a complex non-traditional flow. The backward logistics is commonly known as reverse logistics (in the following the general term “reverse logistics” will be applied). Logistics is about managing the movement of product or services whether flowing backward or forward in the supply chain context [16]. Figure 1.0 illustrates the concepts of forward and reverse logistics. Forward Logistics is “the process of planning, implementing and controlling, and storage of goods, services and related information in the most efficient and effective way, from the point of origin to the point of consumption to meet consumers requirements” [17].

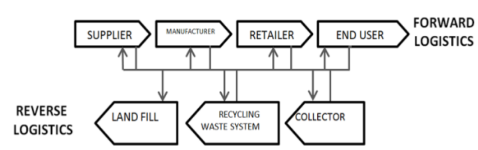


**Figure 1.0**: Forward and Reverse Logistics

The notation of forward logistics (Fig. 1.0) was under the assumption of the product or services received or consumed at the point consumption within the supply chain (SC). However, the logistics flow within SC does not merely represent a linear process but a rather complex two-way or multi-level process [18]. And reverse logistic (RL) (Fig. 1.0), however, mainly comprises from all the processes of product and information that are essential to recapture used, returnable, damaged, end-of-life, packaging materials, production scraps and other waste and recover the waste back to the point where it can be reused, remanufactured, recycled or disposed properly [19].

### 2.2. Symbiosis Perspective and Awareness Level

In Shah [20] reported more than 90% households have used e-goods (electronic and electrical equipment) however, most of the 90% e-good users were lacking knowledge and experience on WEEE recycling disposal routine [6]. In addition to the likes of awareness campaign that promotes effective recycling disposal of WEEE; two significant attributes that important in mitigating MSW especially WEEE: reverse logistics factor (situational) and behavioral factors (personal) [8]; [21]. These two factors interacted symbiotically as the awareness level or the level of engagement is heightened [8]. The definition of a symbiosis is an interaction between two different entities in close physical association, typically to the advantage of both, [22]. The key element from the Oxford [22] definition of symbiosis is the element of interaction between two different entities. Whereby, the symbiosis effect suggested in this study is an interaction between situational and personal factors that are represented respectively by the WRDS from the municipalities and the e-good users. The symbiosis effect between the recyclers (e-good users) and providers (municipalities) instigates the recovery of materials which can ultimately re-enter the supply chain.

## 3. Methodology

The approach used was based on the quantitative approach to a survey design. The target participants for this study were tertiary level students enrolled in a university program. Students at the tertiary level were considered as applicable to this study due to e-goods such smartphones and tablets are a necessity for means of communication and learnings [23]. The sampling method of a stratified sampling technique has been employed and only 450 respondents are willing to participate the survey undertaken. The profile of the sample is tabulated in Table 1.0.

**Table 1.0:** Respondent Demographic Details (N=450)

| Item | Category | N (450) | Percentage (100) |
|---|---|---|---|
| **Gender** | Male | 181 | 40.2 |
| | Female | 269 | 59.8 |
| | | | |
| **Age** | 20 or under | 113 | 25.1 |
| | 21-25 | 251 | 55.8 |
| | 25-30 | 46 | 10.2 |
| | 31 or above | 40 | 8.9 |
| | | | |
| **Level of Study** | Undergraduate | 349 | 77.6 |
| | Postgraduate | 101 | 22.4 |
| | | | |
| **Years of Study** | Year 1 | 156 | 34.7 |
| | Year 2 | 157 | 34.9 |
| | Year 3 | 88 | 19.6 |
| | Year 4 | 49 | 10.9 |
| | | | |
| **Residential Area** | City | 226 | 50.2 |
| | Urban | 98 | 21.8 |
| | Sub-urban | 87 | 19.3 |
| | Rural | 39 | 8.7 |

The demographic analysis of the respondents was profiled whereby; sample representation from the university e-good users is represented by 269 females and 181 males aged between (21 – 25 and 20 - under) age group, participations from the population samples were recruited via convenience sampling from students of Universiti Utara Malaysia. More females (60%) than males (40%) participated in the survey. This was consistent with past research in recycling [24] which noted that apparently, more women were likely to participate in research where environmental issues are a major concern.

## 4. Finding and Discussions

The aim of this study was to explore the notion of a "symbiosis perspective" and intended to be both confirmatory and revelatory. Consistent with previous findings, the facilitation of reverse logistics in governing WEEE has been found significantly relates to awareness level of the e-good users. The first analysis of correlation has been applied and the two factors included personal and situational are positively correlate with the awareness level of the e-good users in regards to WEEE (Table. 2.0).

**Table 2.0:** Correlation Table (N=450)

| Item | Situational Factor(s) | |
|---|---|---|
| **Pearson Cor. (Sig.)** | **Engagement** | **Supporting Facilities** |
| Personal Factor (Awareness Level) | 0.49 (0.0) | 0.36(0.0) |

A correlation was also performed with personal factors and situational factors as shown in Table 2.0. The results showed that the personal factors of awareness level had a significant relationship with supporting facilities ($p < 0.01$) with positive correlation ($r$ (450) = +0.49); as well as engagement ($p < 0.01$) with positive correlation ($r$ (450) = +0.36). Pearson's correlation analyses have revealed that awareness level has a strong positive relationship with situational factors. An incremental change in engagement program and facilities by the authorities will have a positive effect on the awareness level of the e-good users [3] even though in the study found a positive relationship between awareness level with facility and engagement, but with a rather moderate and weak intensity.

To further analysis the correlation, this study applied multiple regression analysis to test if the interaction between personal and situational factors (implying the symbiosis effect) significantly predicted e-good users' awareness level. This analysis was relevant as it addressed the assessment of various relationships, using the information from independent variables to improve the accuracy in predicting values for the dependent variable [25]. The results of the regression indicated the two predictors explained the mutually dependent predictors significantly affected awareness level of e-good users in regards to WEEE (Table. 3.0). The results of the regression indicated the two predictors explained 76.2% of the variance ($R^2$=0.76.2; overall model fit). The main effect of all predictors were significant, f (2,495) = 153.34; MSE = 25.82, p<0.01 (Table. 3.0). It was found that the interaction of personal factors significantly (Table. 4.0) affected by situational factors of supporting facilities and engagement (β = +0.15, P<0.01; β = +0.38, P<0.01)

**Table 3.0:** Model Fit and Univariate ANOVA

| Model | R | R Square | Adjusted R Square | Std. Error of the Estimate |
|---|---|---|---|---|
| 1 | 0.873 | 0.762 | 0.749 | 874.779 |
| ANOVA | | | | |
| 1 | Sum of Squares | Df | Mean Square | F(Sig.) |
| Regression | 8126.171 | 2 | 4063.085 | 157.337 (0.00) |
| Residual | 12782.914 | 495 | 25.824 | |
| Total | 20909.084 | 497 | | |

a. Predictors: (Constant), situational factors

**Table 4.0:** Model Coefficients

| Model | Unstandardized Coefficients | | Standardized Coefficients | T(Sig.) |
|---|---|---|---|---|
| | B | STD.ERROR | Beta | |
| 1 (Constant) | 2.127 | 0.213 | | 9.976(0.0) |
| Supporting Facilities | 0.150 | 0.035 | 0.100 | 4.527(0.0) |
| Engagement | 0.375 | 0.040 | 0.410 | 9.324(0.0) |

To sum up the analyses, the awareness level is a key important element in reverse logistics for WEEE which consistently with Bilen's [13] work which stresses the importance of public awareness programs for e-good users' disposal habits from the source [3]. Hence, the interactions between personal and situational factors depicted a symbiosis understanding of the predictor factors: supporting facilities and engagement.

## 5. Conclusion

Recycling and RL have been co-examined in a small number of studies. To date, the studies in core Supply Chain Management journals have examined RL in the context of recovering and recycling plastics, [26], household medicines [27] and hospital waste [28]. This study has therefore provided a contribution to the previously underexplored context of RL and recycling WEEE, more specifically to the context of e-good users' awareness level and the facilitation of WRDS. This study, therefore, should have an interdisciplinary interest in both the SCM and waste management scholars. From a practical perspective, the findings should inform WRDS operators looking to more effectively manage WEEE and enhance recycling and sustainability. The lacking of awareness level for WEEE disposal is visible in the e-good users; hence, improving the relationship between service user and service provider is to the mutual satisfaction of both. RL practitioners should introduce systems to support the recovery of WEEE in sympathy with communication and education initiatives to affect e-good recycling behaviour (ERB) especially in WEEE and should also appreciate a symbiosis perspective in the design of recycling WRDS. Findings confirm the existence of a symbiosis effect between situational and personal factors and inform current research trends in the environmental sciences, behavioural and logistics literature, particularly identifying consumers as being an important pivot point between forward and RL flows. The social implications of improved recycling performances in municipalities are profound. Even incremental improvements in the performance of WRDSs can lead to enhanced sustainability through higher e-recycling rates, reduced diversion of MSW to landfill, decreases in pollution levels, reduced carbon footprints and reduction in depletion of scarce natural resources.

## Acknowledgments

The author would like to thank Tg Faisal Tg Arifin; Mohamed Omar Abow and Abdulkadir A. for doing the fieldwork for this project.

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