MATERIAL FLOW ANALYSIS AND AWARENESS ON E-WASTE MANAGEMENT

Gautam Lalit Shah, Mohd Badruddin Mohd Yusof * & Ng Ga Ming

Faculty of Civil Engineering, Universiti Teknologi Malaysia, Skudai, Malaysia

Corresponding Author: mbadruddin@utm.my

Abstract: E-waste management is currently seen as an important environmental component and has received a worldwide attention. E-wastes in Malaysia are commonly disposed along with other domestic wastes at landfills, thus has caused a major concern amongst the public and the government. This method has been practiced in many developing countries which lack the proper disposal method of e-waste. A study was conducted in Skudai, Johor to analyze the level of awareness of Material Flow Analysis (MFA) among the public and retailers, as well as their views on current e-waste management from different aspects. The primary data was obtained through interview and questionnaire distribution. The sets of questionnaires that were distributed to public, computer retailers and hand-phone retailers were 200, 21 and 26, respectively. The analysis was done by using Microsoft Excel and SPSS software. The result shows that the level of awareness among public, computer retailers and hand-phone retailers was low where the percentages who did not know about MFA were 52, 76 and 77 percent, respectively. The study found that demographic background did not affect willingness to recycle and reduce e-wastes. However, from the correlation analysis, it shows that there are significant correlation between interest of respondents toward environmental activities and willingness to practice MFA for both computer retailers and hand-phone retailers where $p < 0.05$ at significant level of 95%. Spearman's rho correlation coefficient was used to determine the significant level. Then, linear regression analysis also shows that for public respondent, people who had joined environmental activities before tend to perform MFA on e-waste management with more information at significant level of 95% ($p < 0.05$). This study implies that more environmental campaign should be performed in order to increase general knowledge of MFA among the public. The results of this study will assist the Malaysian waste management authorities to plan the collecting system and facilities needed for management of e-waste generated in the near future.

Keywords: *E-waste, mobile phone, storage, consumer behavior, questionnaires*

1.0   Introduction

Malaysia has generated 40,000 tons of e-waste in 2006, according to the DOE, (NST Online, 2007). It only reflects the e-waste that is collected as disassembled components from industries and is much less than the projected value of WEEE for 2006. The total

weight of WEEE will be expected to reach 1.119 million tonnes by 2020. This has called for studies on Material Flow Analysis (MFA) and ways to reduce the wastes as well as to achieve more sustainable e-waste management, globally. There were studies about MFA in Malaysia, but were not related to e-waste. Thus, a study about awareness of MFA will be necessary before further study about MFA on e-waste can be conducted. According to Paul and Helmut (2005), MFA is a systematic assessment of the flow and stocks of materials within a system defined in space and time. The concept of MFA has been adopted in different types of fields like medicine, chemistry, economic, engineering, life sciences and resources, waste and environmental management (Paul and Helmut, 2005). MFA is beneficial for the purpose of predicting the amount of obsolete equipment for electronic appliances from urban households and to analyze the flow after the end of their useful phase (Liu *et al*., 2006). This paper looks at awareness of MFA and willingness to participate amongst the public on resources, waste and environmental management.

2.0   Literature Review

Waste management has been a critical environmental issue in Malaysia. Among the waste, e-waste has been handled as regular garbage and being disposed through landfill and cause impact to environment (Masirin *et. al*., 2008). This has been practiced by many countries and has resulted in lead leachate pollution (Spalvins *et al*., 2008). Current rapid advancement in technology has resulted in development of new electronic devices thus leading to short life-span of electronic products and subsequently a huge amount of electronic waste (e-waste) was generated.

Electronic waste is a problem when an obsolete product has to be replaced, and old equipment discarded. Growth in an electronic sector and rapid changes in ICT technology lead to the situation whereby, more consumers are generating more volumes of waste electronic equipment, even though they are still functioning. Replacement of the electronic products has been the result of this ever changing technological advancement.

Due to insufficient method of proper e-waste management system and low awareness among the public about the potential hazardous of e-waste towards the environment, concerns among researchers have increased. Pollution due to improper management has subsequently threatens the human life. New ways should be sought to change the situation without decreasing the quality of life. Consumers' involvement along with understanding of their behavior is paramount in making waste management effective (Yusof, 2004). Therefore, environmental assessment on e-waste management should be conducted in order to minimize the environmental impact.

Material Flow Analysis can be implemented to assess the environmental impact due to E-waste. MFA is useful as a parameter in decision making and management where damage toward environmental can be minimized. However, MFA is at its infant stage and appears foreign to many Malaysians. Thus, it is important to study about the awareness among public toward MFA and also concern about issues of e-waste since one must have sufficient knowledge and awareness before MFA can be implemented in Malaysia.

A previous study on MFA in Malaysia by Ghani and Mahmood (2008) looked at the application of Material Flow Analysis as decision support tool for planning and sustainable management where MFA was used to describe the metabolism of phosphorus in a specific Malaysia region. The study shows that there were three major components that involved in phosphorus balance of Malaysia agriculture and highest phosphorus amount was generated by P-removed of agriculture soil. Other studies about sustainability of solid waste management in Malaysia has been conducted with the application of MFA as the assessment for analysis and in order to get precise understanding of the processes that cause increment of waste output in Malaysia (Siti,2012) indicating a weaknesses in national waste management system in Malaysia, with a lack of strategic policy and management. All these setbacks have been said to affect the success in sustainable development.

3.0   Methodology

The study mainly consists of desk study, data collection and analysis of data. Desk study helps to identify the problems of the study and subsequently provide information in developing questionnaire. List of questionnaire was generated for purpose of collecting data, secondary data and desk study was used as reference when develop the questionnaire. This study was conducted in Skudai, Johor. Questionnaire paper of this study was divided into four parts which included basic information of the respondent, level of awareness towards recycling, e-waste management and MFA. The survey was conducted among those aged 18 to 55 years above, including respondents from public, computer retailers and hand-phone retailers. There were a total 200 respondents from public, 26 respondents for hand-phone retailers and 21 respondents for computer retailers. Analysis of the data collected was conducted by using Microsoft Window Excel and SPSS statistics software for both descriptive and inferential statistic. Tables and charts were used to describe descriptive statistic while linear regression and bivariate analyses were used. The determinant variable is considered significant if p-value is less than 0.05 (95-percent confident level) or less than 0.01 (99-percent confident level), where Spearman's rho correlation is used to determine the significant levels.

The main objectives of the study include:

1. To study the level of awareness of public and retailers on general issues in e-waste management.
2. To study the level of awareness of MFA among the public and retailers.
3. To find out the feasibility of MFA to be implement in the management of e-waste and so that to have a sustainable environment.

4.0 Results and Discussion

4.1 Background of Respondents (Descriptive Statistics)

Figure 1 shows the descriptive statistic (percentage) of male and female for respondent from hand-phone retailers, computer retailers and public. Figure 1 shows that frequency of male respondents (hand-phone retailers) occupied 61.5%, while male (from computer retailers) 81%. However, female respondents (public) are 45% in comparison to male counterparts (45%).
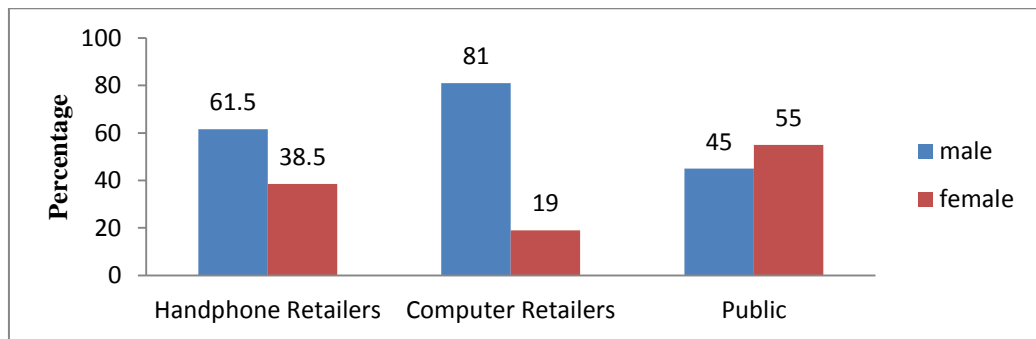

Figure 1: Gender of respondents

Figure 2 shows the educational level of the respondents. It shows that majority of the hand-phone retailers have low education level (89% with only secondary education level), while public respondents consists of 72% finished secondary education level. For computer retailers, however, majority of them (48%) had a college degree. This is due to the fact that the presence of the Universiti Teknologi Malaysia campus located nearby the study area.
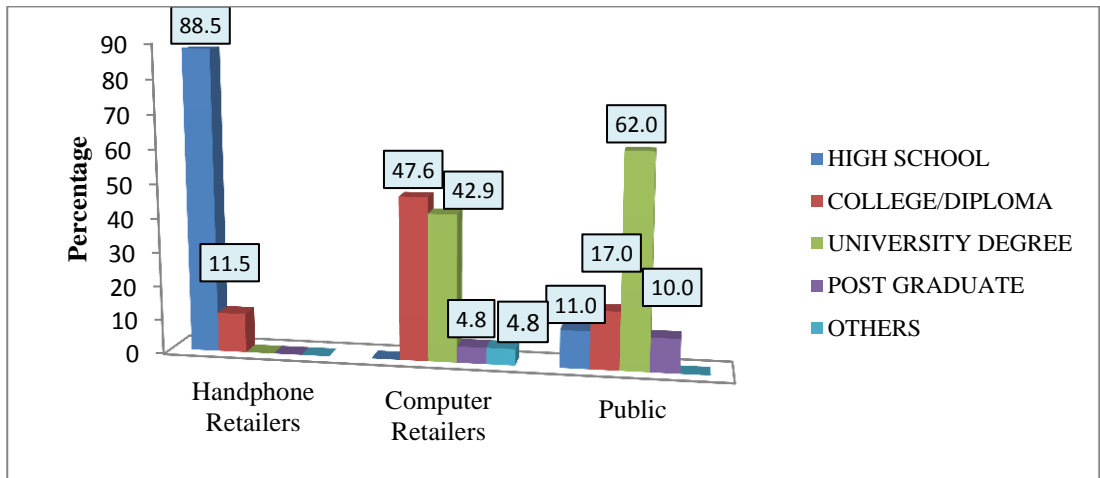
Figure 2: Educational background of respondents

4.2 *Awareness of Respondents towards Recycling (Descriptive Statistics)*

In order to have further understanding about the awareness of respondent on the recycling issues, previous involvement in environmental activities of the respondents were determined. Table 1 shows that majority of respondents from computer retailers (91%) and hand-phone retailers (89%) had not joined environmental activities before. Meanwhile, almost half of the public respondents had joined environmental activities before. Mean values for all three groups of respondents indicated that most of them were not involved in environmental activities.

Table 1: Respondents' previous experience in environmental activities.

OPINION	Hand-Phone Retailers		Computer Retailers		Public	
	Frequency	%	Frequency	%	Frequency	%
No	23	88.5	19	90.5	88	44
Neutral	3	11.5	2	9.5	18	9
Yes	0	0	0	0	94	47
Total	26	100	21	100	200	100
Mean	1.1		1.1		2.2	
Std. Deviation	0.3		0.3		1.0	

* Question: "Have you joined any environmental friendly activities before?" Where: 1= "No", 2=
"Unsure/Neutral", 3= "Yes")

Table 2 shows public respondents were more interested to recycle used items as compared to the retailers. About 54% of the public respondents showed interest with recycling. However none of computer retailers and only 19% of hand-phone retailers showed interest in recycling. The mean values of hand-phone retailers, computer retailers and public were 1.5, 1.4 and 2.0, respectively, which indicated that low level of interests in recycling.

Table 2: Respondents' interest to practice recycling

OPINION	Hand-Phone Retailers		Computer Retailers		Public	
	Frequency	%	Frequency	%	Frequency	%
No	17	65.4	12	57.1	92	36
Neutral	4	15.4	9	42.9	20	10
Yes	5	19.2	0	0	108	54
Total	26	100	21	100	200	100
Mean	1.5		1.4		2.0	
Std Deviation	0.8		0.5		0.9	

Note. Question: "Are you interested in recycling activities?"; (Where: 1= "No", 2= "Unsure/Neutral", 3= "Yes")

From Table 3, public respondents show that they tend to have higher awareness toward recycling. It shows that 46% of the public were willing to join recycling campaign of e-waste. In contrast, 50% of hand-phone retailers and 61.9% of computer retailers were not willing to join recycling campaign about e-waste. The mean values for the three groups of respondents were lower indicating they were not willing to join campaign about e-waste.

Table 3: Respondents' willingness to join recycling campaign about e-waste.

Opinion	Hand-Phone Retailers		Computer Retailers		Public	
	Frequency	%	Frequency	%	Frequency	%
No	13	50	13	61.9	44	22
Unsure/Neutral	6	23.1	4	19	64	32
Yes	7	26.9	4	19	92	46
Total	26	100	21	100	200	100
Mean	1.8		1.6		2.2	
Std Deviation	0.9		0.8		0.8	

Note. Question: "Are you interested in recycling activities?" Where: 1= "No", 2= "Unsure/Neutral", 3= "Yes")

Respondents were asked of their other waste-reduction and environmental behaviors, such as sorting of wastes at home and willingness to pay more for green products. Table 4 shows that 55% of public respondents in Skudai did not perform separation and recycling of e-waste, even though they have higher awareness toward recycling. It translates that environmental awareness was not reflected in actual behavior. Moreover, only 26% of the public respondents were willing to pay for 'green' (environmental-friendly) electronic devices.

Table 4: Respondents' separation and recycling activities of e-waste and willingness to pay for green electronic device (Where: 1= "No", 2= "Unsure/Neutral", 3= "Yes").

Opinion	Separate and Recycle E-waste		Willingness to Pay for Green Electronic Device	
	Frequency	%	Frequency	%
No	110	55	56	28
Unsure/Neutral	30	15	92	46
Yes	60	30	52	26
Total	200	100	200	100
Mean	1.8		2.0	
Std Deviation	0.9		0.7	

*Note. Question: "I have separated and recycle e-waste", "I am willing to pay for a green electronic device"; Where: 1= "No", 2= "Unsure/Neutral", 3= "Yes")

4.3   Awareness towards E-waste Management

This section describes the awareness of respondents on e-waste management, analyzed using descriptive and inferential statistics.

4.3.1   Public Respondent (Descriptive Statistics)

According to Table 5, the result shows that over half of the respondents (54%) think that e-waste can be sold and only 20% think that it is a waste, while 26% agree that e-waste is hazardous. This indicates that their awareness of the danger of e-waste will cause environmental impact. Less than half or 42% of respondents were concerned about impact of e-waste toward environment, with about one-third or 36% believed that the impact is not related to their daily business lives (Table 6).

Table 5: Understanding of respondents about e-waste

Opinion	Understanding about e-waste	
	Frequency	%
Waste	20	20
Can be sold	54	54
Hazardous Item	26	26
TOTAL	100	100

Note. Question: "What do you understand about e-waste?"

Table 6: Concern of respondents toward impact of e-waste

Opinion	Concerns about e-waste	
	Frequency	%
Yes	88	42
No	68	36
Unsure	44	22
Total	200	100
Mean	1.8	
Std Deviation	0.8	

Note. Question: "Are you concerned about impact of e-waste toward environment?" Where: 1= "No", 2= "Unsure/Neutral", 3= "Yes")

4.3.2   Awareness amongst Public Respondents

Bivariate analysis was used to analyze the relationship between variables whether there was significant correlation between dependent and independent variables.   The dependent variables used were knowledge about e-waste, concern about impact of e-waste, while the independent variable, education level. Spearman's rho correlation coefficient was used to analyze the significant levels among variables since the variables are non-parametric.

Table 7 shows that understanding about e-waste has significant positive correlation with the concern about impacts of e-waste and education level where, $p < 0.05 (r = 0.231)$ and $p < 0.05 (r = 0.209)$, i.e., at 95 percent significant level, respectively. The correlation shows that people with higher education level also have higher understanding towards e-waste. Meanwhile, the correlation shows that better understanding toward e-waste will lead to higher concern about impact to the environment due to e-waste.

Table 7: Correlation between knowledge and concern about impact of e-waste (Bivariate Analysis)

Questions	Knowledge of e-waste	
	Spearman's rho Correlation Coefficient	*p* (2-tailed)
Concerns about impact of e-waste?	0.231*	0.021
Education	0.209*	0.037

*Note. *. Significant at the 0.05 level (2-tailed).*

4.3.3 Retailers (Descriptive Statistic)

Majority of the retailers had no proper e-waste management and low level of awareness toward e-waste management (Table 8)... Almost half (48%) of computer retailers chose to throw away the unusable computer parts. It appears that the e-waste was treated similar like other domestic wastes by ignoring the effect to the environment. Meanwhile, 58% hand-phone retailers chose to return the unusable hand-phone parts to owners, while the other wastes will be thrown without proper management.

Table 8: Retailers handling of unused parts

Method	Computer Retailers		Hand-phone Retailers	
	Frequency	%	Frequency	%
Dispose	10	47.6	11	42.3
Sell	2	9.5	0	0
Return to owner	6	28.6	15	57.7
Recycle	3	14.3	0	0
TOTAL	21	100	26	100

Note. Question: "How do you handle the unusable computer spare part?", "How do you handle the unusable hand-phone spare parts?"

Table 9 shows the way computer retailers handled the malfunctioning computers. The majority had low awareness on e-waste management since 28.6% of them chose to dispose off the computers and only 38.1% chose to collect functioning parts and throw malfunctioning parts without considering the potential environmental impact.

Table 9: Respondents' handling of malfunctioning computers

Method of handling	Frequency	%
Dispose	6	28.6
Recover usable and dispose malfunctioning parts	8	38.1
Recycle the whole device in one piece	5	23.8
Collect functioning part and recycle malfunctioning part	2	9.5
TOTAL	21	100

Table 10 shows the way hand-phone retailers handle old phones. Most of the retailers chose to repair and resell (42.3%) the cell phones since the phone were still functioning. However, 26.9% chose to dispose the hand-phones indicating that hand-phone retailers had low awareness on e-waste management. Regrettably, they currently do not have any systematic way to manage e-waste.

Table 10: Respondents' handling of old hand-phone

Method of handling	Frequency	%
Dispose	7	26.9
Keep as spare	8	30.8
Repair and sell	11	42.3
Send to recyclers/recycling center	0	0
TOTAL	21	100

4.4 Awareness of MFA and E-waste management

4.4.1 Knowledge of Respondents to MFA (Descriptive Statistic)

Table 11 shows whether the respondents know about MFA. The result shows that most of the respondents regardless of group (public or retailers) did not know about MFA. In order to implement MFA, more promotion and study about MFA should be carried out and let people know about the usage of MFA. Figure 3 shows public, computer retailers and hand-phone retailers strongly admitted the fact, with the percentages were 12, 19 and 3.8, respectively.

Table 11: Respondents' knowledge about MFA

Opinion	Hand-Phone Retailers		Computer Retailers		Public	
	Frequency	%	Frequency	%	Frequency	%
No	20	76.9	16	76.2	104	52
Neutral/Unsure	5	19.2	5	23.8	76	38
Yes	1	3.8	0	0	20	10
Total	26	100	21	100	200	100
Mean	1.3		1.2		1.6	
Std Deviation	0.5		0.4		0.7	

Note. Question: "Have you heard about Material Flow Analysis (MFA)?" Where: 1= "No", 2= "Unsure/Neutral", 3= "Yes").

The statement is true that MFA is environmental assessment of e-waste management. This indicates that most of the respondents know slightly what MFA was. The mean values of public, computer retailers and hand-phone retailers were 3.5, 2.9 and 3.8, respectively. This indicates that respondents agreed with the statement. (i.e., 1= "Strongly Disagree", 2= "Disagree", 3= "Neutral", 4= "Agree", 5="Strongly Agree").
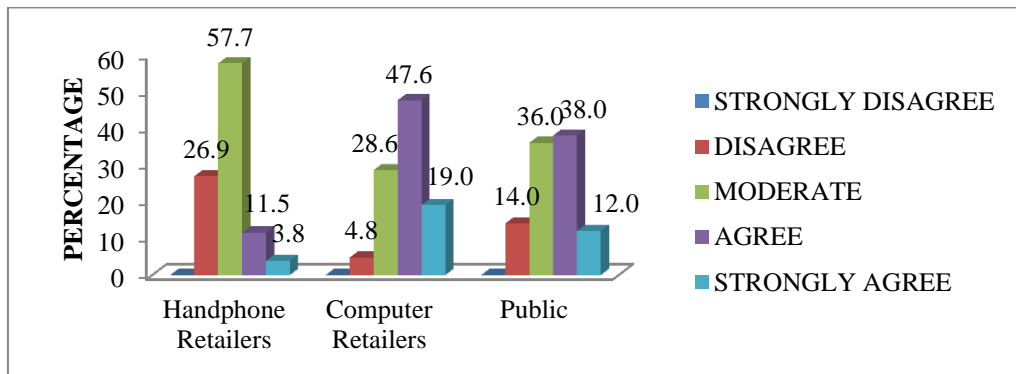

Figure 3: Opinions on MFA as an environmental assessment of e-waste management

Figure 4 shows opinions on MFA as a management parameter for policy maker. This statement was correct where MFA was used for development planning in order to have sustainable future. Majority of public (40%) and computer retailers (48%) disagreed with this statement, while 8 percent of hand-phone retailers strongly agreed. The mean values of public, computer retailers and hand-phone retailers were 2.2, 2.8 and 1.9, respectively. This indicates that respondents did not agree with the statement. This implies that most of the respondents do not know about MFA. They only know briefly

that MFA is a part of an environmental assessment and is relevant in handling environmental issues.
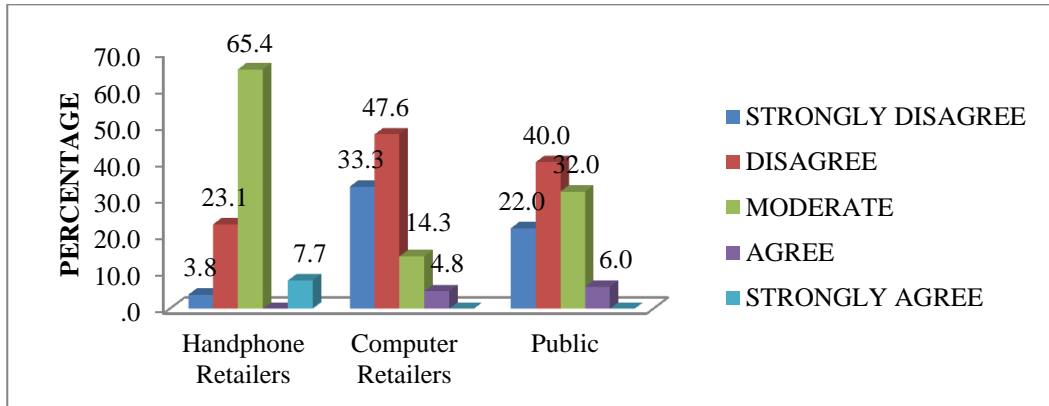

Figure 4: Opinions on MFA as a management parameter for policy maker

4.4.2   *Cross Tabulation (Hand-phone Retailers)*

By using cross tabulation analysis, correlation between personal interest in environmental activities (independent variable) and two dependent variables (i.e., willingness to perform MFA with incentives given and willingness to perform MFA with sufficient information) have been analyzed. Table 12 shows the correlation between the variables. It shows that the interest in environmental activities is significantly related to willingness to perform MFA on e-waste management with sufficient information ($p < 0.05$). Thus, there is evidence to support any strong correlation between these two variables. The null hypothesis indicating that the interest in environmental activities has no relationship with willingness to perform MFA on e-waste management with sufficient information is therefore rejected.

Table 12: Correlation between interest in environmental activities and willingness to perform MFA (Cross Tabulation)

Variables	Interest in environmental activities
	Significant *p*
Willingness to involve on e-waste management if given sufficient information	0.023
Willingness to involve in e-waste management with incentives given	0.001

Interest in environmental activities has significant correlation with their willingness to perform MFA on e-waste management if given incentives (p <0.01). Thus, there is evidence to support correlation between these two variables at a significant at 99 percent confident level. It is therefore important to note that in order to encourage implementation of MFA, more incentives or campaign should be given or organized to increase level of interest of people. By increasing level of interest will help to increase the awareness of respondents toward MFA on e-waste management.

4.4.3   Linear Regression (Public Respondent)

From bivariate analysis, two variables show significant correlation which was willingness to perform MFA on e-waste management and respondents' prior involvement in environmental activities. The same variables were analyzed in the linear regression analysis by using stepwise method. The dependent variable refers to willingness to perform MFA on e-waste management with sufficient information and the independent refers to respondents' prior involvement in environmental activities. From analysis, p-value is less than 0.05 (0.045) which also means that both variables are significantly correlated, with R^2 obtained 0.04.

Basically, linear equation

$$Y = C + M*X \qquad\qquad (1)$$

and linear regression:

$$WTP = 2.518 + 0.252*JA \qquad\qquad (2)$$

Where, WTP = willingness to perform MFA on e-waste management with provided information/campaign

JA   = respondents' prior involvement in environmental activities

This indicates that people who has joined more environmental activities before tend to perform MFA on e-waste management if given more information.

4.4.4   Bivariate (Computer Retailers)

The variables analyzed were willingness to perform MFA on e-waste management with sufficient information given and interest of respondents in environmental activities. Spearman's rho correlation coefficient was used to analyze the significant levels among variables. Table 13 shows that interest in environmental activities has significant positive correlation with willingness to perform MFA on e-waste management with sufficient information ($r = 0.459$), ($p < 0.05$), i.e., significant at 95 percent level of confidence.

Table 13: Correlation between interest in environmental activities and willingness to perform MFA with sufficient information (Bivariate Analysis)

Variable	Interest in environmental activities	
	Spearman's rho Correlation Coefficient	p (2-tailed)
"Willing to perform MFA on e-waste management with provided information"	0.459*	0.036

*Note: *. Significant at the 0.05 level (2-tailed)*

The correlation shows that the higher the interest of respondents in environmental activities causes respondents tend to perform MFA on e-waste management with more information available. This also indicate that interest of respondent toward environment activities will be one of the factor that affecting the feasibility to implement MFA.

5.0   Conclusion and Recommendation

From the analysis, it can be concluded that majority of respondents have low awareness of e-waste management and do not practice recycling of e-waste. Computer retailers and hand-phone retailers mostly dispose the broken spare parts along with other solid wastes, i.e., 47.6% and 42.3% respectively. Half of the public (55%) do not separate and recycle e-waste. Most of the respondents in Skudai area have low awareness toward MFA. From the correlation analysis (computer retailers), there are positive correlation between "interest of respondent toward environmental activities" and their willingness to involve in MFA on e-waste management if more information were provided. The study showed correlation between hand-phone retailers' interest toward environmental activities and willingness to involve in e-waste management (if given sufficient information).

Linear regression analysis for public respondent shows that people who has joined more environmental activities before (JA) also tend to involve in e-waste management with more information (WTP) at significant level of 95% ($p < 0.05$). The study support with hypothesis that awareness of MFA was low among the public and retailers at Skudai area. This study indicated that some improvements are needed to increase the level of awareness of MFA. The recommendations include:

i.   The need to promote environmental awareness to general public by increasing number of environmental courses in all education levels.

ii.   Conduct campaign, workshops and activities related to environmental issues especially on the danger and effects of improper e-waste disposal. This will remind public of the current environmental issues and encourage them to recycle in their daily life.

iii.   Government should improve environment policy and ensure all level of society will follow the rules strictly. Waste management issues in Malaysia can be improved with complete environmental management system.

However, due to the nature of the location and sample size of the study, these results should be accepted to represent the study at the specified location and time of study, and not used to reflect the overall population of Johor State or Malaysia in general. However, it seems to imply the underlying weakness in understanding the role of MFA in the overall benefits in e-waste management.

6.0   Acknowledgements

References

Ghani L.A. and Mahmood N.Z. (2008). Application of Material Flow Analysis (MFA) for Decision Support Tool for planning and sustainable management: Phosphorus as a Case Study in Malaysia Agriculture. Section 5. Industrial sustainability and ecology of LCA. Page 84-85. University Malaya.

Liu, X., Tanaka, M. and Matsui, Y. (2006). Generation amount prediction and material flow analysis of electronic waste: a case study in Beijing, China.

Masirin M.I.., Ridzuan M.B., Mustapha S. and Adon R. PSIS Enviro (2008). An Overview of Landfill Management and Technologies: A Malaysian Case Study at Ampar Tenang. 1st National Seminar on Environment, Development & Sustainability.

NST Online (2007). Spotlight: E-waste. Assessed on 26th of September 2007.

Paul H.B. and Helmut R. (2005), Practical Handbook of Material Flow Analysis. Lewis Publishers, United States.

Siti A.S. (2012). Analysis Sustainability of Solid Waste Management in Malaysia using Ecological Modernisation Perpective. Department of Civil Engineering: University of Strathclyde.

Spalvins E., Dubey B., Townsend T. (2008). Impact of electronic waste on lead concentration in landfill leachate. Environmental Science Technology 2008.

Yusof M.B.M. (2004)., "The Effects of Socio-Economic Characteristics on Household waste in Johor Baharu District," PhD Thesis Faculty of Civil Engineering University Technology Malaysia , 2004,