Design of Questionnaire for the Study of Consumers' Awareness and Behavior towards Electronic Waste (E-waste) Collection and Recycling

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Abstract:

The rapid obsolescence of electrical and electronic equipment has produced the unstoppable electronic waste streams. This large waste stream, which contains many hazardous and toxic substances, has caused many negative effects on the environment and human health. Therefore, the sustainability mission to reduce the amount of e-waste has been gradually embraced by many countries, organizations, and companies. To successfully solve the e-waste recycling problem, it is important to focus on one of the most crucial phases which is e-waste collection system. To operate the effective e-waste collection system, it is necessary to understand the consumers' awareness and behavior toward e-waste collection and recycling. There are many existing studies that focus on determining household consumers' awareness and behavior towards e-waste collection and recycling. To accurately determine the consumers' awareness and behavior, it is necessary to effectively design the questionnaire. The effective questionnaire focuses on some essential points, including (1) demographic information, (2) residential condition, (3) consumers' awareness, (4) e-waste recycling habit, (5) convenience of recycling service, (6) economic benefit, (7) type of e-waste and (8) consumers' willingness and behavior, to best meet the evaluation of the consumers' awareness and behavior to engaged in e-waste collection and recycling. This paper is to design the questionnaire to determine the awareness and behavior of consumers towards e-waste collection and recycling. For this purpose, many papers studied on customers' awareness and behavior were reviewed and analyzed. Moreover, this paper introduces the procedure to identify the consumers' willingness and behavior toward e-waste collection and recycling. The observations and analysis from the survey data will bring up the implications on the amount of e-waste that would be recycled, the locations of drop-off

points/containers, and the minimum number of the e-waste collection vehicles and their shortest route.

1. Introduction

Accelerated and advanced development of the electronics industry in the 21st century is creating the rapid obsolescence of electrical and electronic equipment. Electronic waste, commonly known as e-waste, waste electrical and electronic equipment, or end-of-life electronics, refers to deemed obsolete or unwanted electronic and electronic equipment, including all components, sub-assemblies, and consumables [1]. Electronic waste is one of the most important waste streams on our planet with 42 million tons generated in 2014 and the annual growth rate of 5% [3]. Moreover, e-waste consists of hazardous constituents that adversely impact the environment and human health. For example, there are more than 1000 toxic substances associated with e-waste including toxic metals and persistent organic pollutants [2]. Unlike traditional waste streams, electronic waste handling and recycling create unique and complicated challenges for society. Therefore, e-waste management is one of the most critical issues in the world. The optimal e-waste management system would be able to overcome the obstacles including the inadequacy of government control, the presence of the informal sector and the lack of consumer awareness. To create an effective e-waste management system, it is necessary to understand the consumers' awareness and behavior towards e-waste recycling.

There are lots of existing studies that focus on determining household consumers' awareness and behavior toward e-waste recycling over the world. Borthakura and Govind did research on the emerging tendency in consumers' e-waste disposal behavior and awareness in many countries over the world including China, Japan, Korea, Thailand, Vietnam, India, Switzerland, Spain, Germany, the United Kingdom, Nigeria, Ghana, the United States, Canada, Brazil, Mexico, and Australia. This research showed that the universal knowledge and experience on consumers' e-waste disposal behavior would provide a significant support for many countries in creating the effective strategies to solve their current e-waste catastrophe [4]. According to Ciocoiu et al. 's analysis on the volume and consumer disposal behavior for e-waste in Romania, consumers still hadn't achieved the e-waste disposal awareness, and this awareness was significantly different between the rural area and the urban area [5]. Perez-Belisa et al. conducted a study on consumer behavior and environmental education in the field of waste electrical and electronic toys in Spain, which indicated that other than the consumers who gave away the unused toys to some social organizations, two-third of the consumers threw them in the trash bin with other types of waste, while the remaining one-third brought their toys to the recycling centers [6]. The study also pointed out that the disposal and recycle habits were significantly dependent on the family size, in which the one-child families discarded toys because they weren't used anymore, whereas the larger families which have three or more children discarded toys because they were broken [6]. Lozano et al. clustered the answers from the survey of consumers' habits and behavior towards replacing and discarding of electronic appliances in Spain, which pointed out that the consumers' behaviors depended on the types of the appliances [7]. The survey that Song et al. conducted to determine Macau civilian's behavior, attitudes, and willingness to pay for recycling e-waste showed that despite of the lack of knowledge in e-waste problems, most citizens were

still willing to bring the e-waste to formal collection centers [8]. Moreover, the positive responses to the "willing to pay" question elevated as the education level and income level increased, while these responses dropped as the respondent's ages decreased, which suggested the investment on education of e-waste recycle for both residents and students [8]. In the study on willingness and behavior towards e-waste recycling for residents in Beijing city, China, Wang et al. mentioned that the primary portion of Beijing's civilians were reluctant to take part in e-waste recycling, as nearly two-thirds of the population still sold electronic scrap to the peddlers instead of the formal e-waste recyclers [9]. Similarly, Li et al. did research on behavior of urban residents in e-waste recycling in Baoding, China. In Baoding, the primary reason for disposing e-waste was malfunctioning, and the primary channel that e-waste was sold was peddlers [10]. The high-income households bought more electronic products, while the college community was the majority that was willing to be charged for e-waste disposal [10]. This research, by analyzing the stream of various e-wastes types, the reasons to dispose electronics, and the consumers' response to the cost of recycling, revealed that the most accurate indicator in the e-waste management system was the separation of consumption patterns in using household appliances, and the price of the electronic products was the most critical factor in choosing recycling methods [10]. Different from Li et al., and Wang et al., Manomaivibool and Vassanadumrongdee assessed the e-waste disposal behavior and future interest of consumers in Thailand. According to them, the primary e-waste collection sector in Thailand was the waste dealer due to their convenient pick-up service, and the large portion of households supported the government's public recycle program without caring too much about financial incentives [11]. In the research on urban citizen's knowledge and awareness on e-waste in Delhi, India, Kwatra et al. showed that the large portion of the middle-class residents had little awareness on problems of e-waste recycling, while for the residents who understood the problem, their main information sources were internet and newspaper [12]. Additionally, these people had no perception about the proper way to recycle and manage e-waste [12]. Saphores et al. studied the United States households' willingness to engage in a pro-environment behavior, which was recycling e-waste at the drop-off centers. According to the study, the households' willingness towards e-waste management was impacted by many internal variables including the convenience of the recycle process, consumers' awareness about e-waste issues, the previous experience in e-waste recycling, gender, and marital status [13]. Interestingly, other factors such as education, age, and ethnicity had insignificant effects; on the other hand, aware on e-waste legislation, accessibility of recycling centers, and salary were not statistically considerable [13]. Furthermore, Saphone et al. established the case study on household willingness to recycle e-waste in California, United States. The case study revealed that, except income and political affiliation, education, environmental beliefs and convenience were the important factors that impacted the intentions to discard e-waste at recycling centers [14]. Nduneseokwu et al., in their work on the fundamental platform to determine the effects of the behavior and the awareness on the consumers' intentions to take part in the formal e-waste management activities, explained that the behavior, the attitude, and the awareness significantly impacted the consumer's engagement in the formal e-waste management activities, while the e-waste management infrastructure neutralized the consumers' behavior and attitude towards e-waste recycling by rapidly transforming the behavior

and attitude into the intentions [15]. Mishima and Nishimura established the survey that investigated the consumers' behaviors in recycling the small-sized e-waste, which led to the fact that the consumer usually didn't want to recycle small e-waste because these types of e-wastes held many private and personal information [16]. The survey also indicated that instead of compensation and reward money, the information security, data transfer, and appropriate education about e-waste were the useful tools to better the e-waste recycle practice [16]. Sabbaghi et al. set up a statistical study of the dynamic character of e-waste to investigate the consumer's e-waste storage and utilization behavior. In this research, by investigating the impact of design feature, brand name, and consumer classification on e-waste lifespan and e-waste's time in storage from the database of 10063 hard disk drives of used computers, Sabbaghi et al. revealed that, without regard to brand name and storage space, the household consumers had stored computers less than commercial consumers had [17]. Also, for various brand names, the heterogeneous trend of e-waste storage behavior was noticed regardless of consumer types as well as storage space [17].

Designing the questionnaire is an important process to accurately determine the consumers' awareness and behavior towards e-waste collection and recycling. The effective questionnaire will lead to the correct evaluation of the consumers' awareness and behavior. This paper aims to design the questionnaire to determine the awareness and behavior of consumers to engage in e-waste collection and recycling. Many papers that studied customers' awareness and behavior were reviewed and assessed. This research also introduced a statistical method to determine the consumers' willingness toward e-waste collection and recycling. The observations and analysis from the survey data will bring up the implications on some important decisions in e-waste management such as the amount of e-waste that would be recycled, the locations of drop-off points/containers, and the minimum number of the e-waste collection vehicles and their shortest routes.

2. Methodology

Awareness is consumer's perception, understanding, feeling, and wisdom. Behavior is consumer's action in the past, current, or in the future. Therefore, the awareness and behavior of e-product customers will reveal the important pattern in their consumption of e-product as well as the generation of e-waste.

2.1. Questionnaire design and data collection

A questionnaire was constructed to obtain the consumers' awareness and behavior to participate in electronic waste collection and recycling. In the beginning of the questionnaire survey, the overall description of the study will be introduced. Moreover, the purpose of the study will be clearly stated. In addition, the importance of the authenticity of the answers was emphasized to minimize the uncertainty of the study. There will be a note to assure that the personal information of respondents is protected and confidential. The scope of e-products will also be specified in the introduction of the survey. The scope of the e-product is determined based on

their weights which is mentioned in detail in the United Nations e-waste statistics [18]. There are seven types of e-products including:

1. PC/Laptop
2. Cell/mobile phone
3. TV/monitor
4. Large home appliances (Dish washer, kitchen equipment (oven, cooking equipment), fridge, freezers, washing machine, dryer, large heating and cooling equipment)
5. Medium home appliances (microwave, household heating and ventilation equipment, A/C)
6. Small electronic equipment (Radio, music instrument, audio set, video recorder, speakers, household tools, vacuum cleaner, printer, leisure equipment, food preparation equipment)
7. Other small electronic equipment (Cameras, portable audio and video devices, lamp, household monitoring and control equipment, telecommunication, small IT equipment (router, mice, keyboard, driver), small consumer electronic (headphone, remote control), small household equipment (small ventilator, irons, clocks, adapter), personal care equipment (hair dryer, razors), household medical equipment, toys, game console)

The questionnaire includes eight parts: (1) Demographic information, (2) residential condition, (3) consumers' awareness, (4) e-waste recycling habit, (5) convenience of recycling service, (6) economic benefit, (7) type of e-waste, and (8) consumers' willingness and behavior to engaged in e-waste collection and recycling. In the first part, the information collected includes the respondents' age range, yearly income, vehicles availability, and the highest level of education. The residential condition part asks question to determine if the respondents rent houses for temporary living, rent houses for living long-term, own a house, or own many houses. The consumers' awareness part will identify the knowledge of consumers in the state law about e-waste recycling, and in the negative effect of material in e-waste on the human health and the environment. Additionally, the e-waste recycling habit shows the questions that identify the respondent's experiences in recycling in the past. Specifically, this part finds out if the respondents have participated in e-waste recycling before. The convenience of the recycling service part discovers how the accessibility of the collection service affects consumers' decisions to bring their old e-product to the drop-off locations or the recycling centers. Moreover, this part determines the reason that prevents consumers to bring e-waste to the drop-off locations or the recycling center. The economic benefits part finds out the influence of economic gain on the consumers' decisions to recycle e-waste. The type of e-waste part explores the effects of different types of e-waste on consumers' awareness to engage in the e-waste collection. The last part, consumers' willingness and behavior, determines the willingness of the consumers to participate in the e-waste collection and recycling, and explores the way that the consumers treat their obsolete e-product.

2.2. Modeling consumers' awareness and behavior towards electronic waste recycling based on correlation and regression

The correlation and regression models are developed to examine the impact of the dependent variables on the consumers' awareness and behavior toward e-waste recycling. According to the questionnaire, there are 12 independent variables including: Age range (X1), income (X2), education level (X3), vehicle availability (X4), type of e-waste (X5), residential condition (X6), awareness about effect on environment (X7), awareness about effect on human health (X8), awareness about law & regulation (X9), recycling habit (X10), convenience of recycling service (X11), economic benefits (X12). The model was shown as a visual representation in Figure 1. The dependent variable is willingness of the consumers towards e-waste recycling collection. Frist, the correlation analysis is performed to determine the independent variables that had a significant effect on the dependent variable, which is the willingness of the consumers towards e-waste collection and recycling. The correlation analysis is performed on the data obtained from the survey to find out which independent variables strongly affect the consumers' willingness to participate in e-waste collection and recycling. The correlation analysis is concerned with measuring the strength of the relationship between variables [19]. In a correlation analysis, the sample correlation coefficient, more specifically the Pearson Product Moment correlation coefficient, is estimated/calculated. The sample correlation coefficient has the values between -1 and +1, and it indicates the direction and strength of the linear relationship between two variables. The correlation between two variables can be positive (for example, higher levels of one variable are associated with higher levels of the other) or negative (for example, higher levels of one variable are associated with lower levels of the other). The sign of the correlation coefficient shows the direction of the relationship. The magnitude of the correlation coefficient presents the strength of the relationship. For instance, a correlation of r = 0.95 indicates a strong and positive relationship between two variables, whereas a correlation of r = -0.1 indicates a weak, negative relationship. A correlation close to zero suggests no linear relationship between two variables [20].

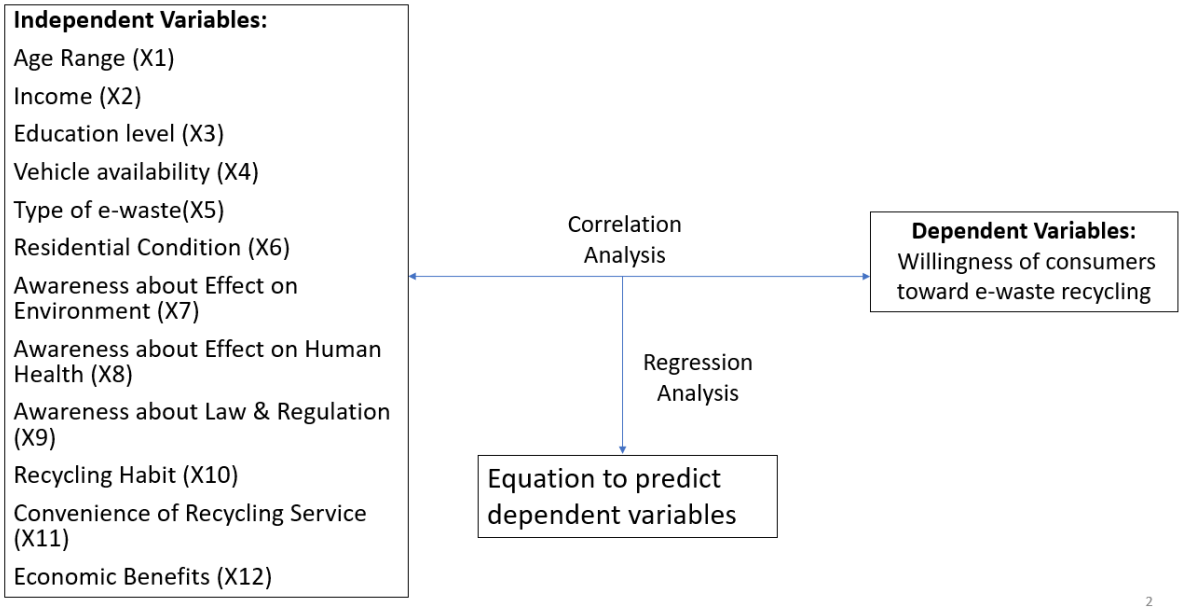

Figure 1: Correlation and Regression model

Second, the regression analysis is conducted to identify the relationship between the independent variables and the dependent variable. The regression analysis is helpful in assessing specific forms of the relationship between variables. The ultimate objective of the regression analysis is to predict the value of one variable corresponding to a given value of another variable [19]. In regression analysis, the interest is the population regression equation that describes the true relationship between the dependent variable y and the independent variable x [19]. In the questionnaire, the question that is designed for the dependent variable is "How do you treat your obsolete e-products?", and five choices are given: (A) throw as normal waste, (B) sell as scrap metal, (C) sell as secondhand goods, (D) bring to collection points/locations, (E) leave in storage, and (F) other. Selection of (B) or (C) or (D) was considered as willing to take part in e-waste collection and recycling.

The regression equation is shown below:

$$y = b_0 + b_1x_1 + b_2x_2 + \cdots + b_ix_i \text{ for i} = 1, 2, \ldots, \text{n} \qquad (1)$$

Where y is the dependent variable, b_0 to b_i are regression coefficients, n is number of independent variables, and x_1 to x_i are independent variables [19].

3. Conclusion

The effective questionnaire will lead to the correct evaluation of the consumers' awareness and behavior toward e-waste collection and recycling, so designing the questionnaire is the crucial process. This paper constructs the questionnaire survey to determine the awareness and behavior of consumers towards e-waste collection and recycling. In addition, this study also introduced a method to determine the consumers' willingness and behavior toward e-waste collection and recycling. The observations, information, and analysis from the questionnaire survey will provide the essential implications on many important decisions in the e-waste management such as the amount of e-waste that would be collected, the locations of drop-off points/containers, and the minimum number of the e-waste collection vehicles and their shortest routes.

4. Appendix A: Questionnaire

Hello everyone,

With the rapid development of electrical industry, the problem of electrical and electronic waste (e-waste) generation and management has become more and more serious worldwide. The growing stockpile of used and obsolete consumer electronic devices has been called the "largest toxic waste problem of the 21st century." There is an urgent task to recycle e-waste efficiently. In order to efficiently recycle e-waste, it is necessary to implement the effective e-waste collection system. It is important to understand the consumers' awareness and behavior towards e-waste collection and recycling in order to design the effective e-waste collection system.

Currently, I am working on determining the factors that affect the consumers' awareness and behavior to participate in e-waste collection and recycling. Your input will play an extremely important part for me to understand how to design an effective e-waste collection system. The

authenticity of your answers plays essential part in the success of the survey. The survey should only take less than 5 minutes, and your responses are completely anonymous.

If you have any questions about the survey, please email me.

Thank you so much. I really appreciate your input for bettering the environment tomorrow!

a. Demographic Information

1. What is your age range?
    a. Under 18 years old
    b. 18 – 20 years old
    c. 23 – 30 years old
    d. 31 – 55 years old
    e. 56 years old or older
2. What is your income?
    a. Less than $25,000
    b. $25,000 to $49,999
    c. $50,000 to $99,999
    d. $100,000 to $149,999
    e. $150,000 or more
3. What is the highest degree or level of school you have completed?
    a. No schooling completed
    b. Some high school, no diploma
    c. High school Diploma
    d. Trade/technical/vocational training or Associate Degree
    e. Bachelor's Degree
    f. Graduate Degree
4. Do you have access to a vehicle that can assist you in bring your e-waste to drop-off points/containers?
    a. Yes
    b. No

b. Residential Condition

1. What is your current residential condition?
    a. Rent for temporary living
    b. Rent for long living
    c. Owned a house
    d. Owned more than one house

c. Awareness

1. How much do you know about the state law about e-waste recycling (Rate from 1 to 10)?
2. How much do you know about the material used in e-waste and their toxic effect on human health? (Rate from 1 to 10)
3. How much do you know about the material used in e-waste and their toxic effect on environment? (Rate from 1 to 10)

d. E-waste Recycling Habit

1. Have you participated in recycling generally before?
    a. Yes, I used to recycle
    b. No, I haven't participated in recycling before

e. Convenience of Recycling Service

1. How far are you willing to drive to drop-off your e-waste?
    a. Less than 1 mile
    b. 1 mile to 5 miles
    c. 5 miles to 12 miles
    d. More than 12 miles
2. Do you have access to e-waste collection/drop-off points?
    a. Yes
    b. No
3. What prevented you from bring your e-waste to collection points?
    a. Lack of drop-off containers nearby
    b. Lack of knowledge about proper e-waste recycling
    c. Lack of vehicles
    d. Lack of time
    e. Don't care

f. Economic Benefits

1. Are economic benefits important in your decision to recycle e-waste?
    a. Yes
    b. No

g. Type of e-waste

1. Are you willing to bring your cell/mobile phones to on campus e-waste drop-off points/containers?
    a. Not willing at all (0% sure)
    b. Not very willing (25% sure)
    c. May be (50% sure)
    d. Willing (75%)
    e. Very willing (100%)
2. Are you willing to bring your TVs/monitors to on campus e-waste drop-off points/containers?
    a. Not willing at all (0% sure)
    b. Not very willing (25% sure)
    c. May be (50% sure)
    d. Willing (75%)
    e. Very willing (100%)
3. Are you willing to bring your PCs/Laptops to on campus e-waste drop-off points/containers?

a. Not willing at all (0% sure)
b. Not very willing (25% sure)
c. May be (50% sure)
d. Willing (75%)
e. Very willing (100%)

4. Are you willing to bring your large home appliances (Dish washer, kitchen equipment (oven, cooking equipment), fridge, freezers, washing machine, dryer, large heating and cooling equipment) to on campus e-waste drop-off points/containers?
    a. Not willing at all (0% sure)
    b. Not very willing (25% sure)
    c. May be (50% sure)
    d. Willing (75%)
    e. Very willing (100%)
5. Are you willing to bring your medium home appliances (microwave, household heating and ventilation equipment, A/C) to on campus e-waste drop-off points/containers?
    a. Not willing at all (0% sure)
    b. Not very willing (25% sure)
    c. May be (50% sure)
    d. Willing (75%)
    e. Very willing (100%)
6. Are you willing to bring your small electrical equipment (Radio, music instrument, audio set, video recorder, speakers, household tools, vacuum cleaner, printer, leisure equipment, food preparation equipment) to on campus e-waste drop-off points/containers?
    a. Not willing at all (0% sure)
    b. Not very willing (25% sure)
    c. May be (50% sure)
    d. Willing (75%)
    e. Very willing (100%)
7. Are you willing to bring your other small electronic equipment (Cameras, portable audio and video devices, lamp, household monitoring and control equipment, telecommunication, small IT equipment (router, mice, keyboard, driver), small consumer electronic (headphone, remote control), small household equipment (small ventilator, irons, clocks, adapter), personal care equipment (hair dryer, razors), household medical equipment, toys, game console) to on campus e-waste drop-off points/containers?
    a. Not willing at all (0% sure)
    b. Not very willing (25% sure)
    c. May be (50% sure)
    d. Willing (75%)

e. Very willing (100%)

h. Consumers' willingness and behavior to engaged in e-waste collection and recycling.

1. How do you treat your obsolete e-products?
    a. Throw as normal waste
    b. Sell as scrap metal
    c. Sell as secondhand goods
    d. Bring to collection points/locations
    e. Leave in storage
    f. Other

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