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RESEARCH ARTICLE

Awareness and Behaviors of Community E-waste Management According to the Circular Economy in Bangkok

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Abstract

This study aims to assess the awareness and behaviors of e-waste management in the public sector according to the circular economy. This study utilized quantitative approaches. Primary data were collected on-site using questionnaires to collect data from 480 samples in Bangkok. The results from the survey show that of the total number of respondents, 409 (85.2%) knew of E-waste, while 370 (77.1%) had a strong understanding of circular economy principles, 339 (70.6%) had a high level of awareness concerning E-waste management following the circular economy, and 367 (76.5%) had a high level of E-waste management behavior in residential areas according to the circular economy. From the analysis, perceptions of E-waste hazards affected the awareness and behavior of E-waste management in residential areas according to the circular economy. However, careers affected the behavior of E-waste management in residential areas according to the circular economy in Bangkok. E-waste management is one of the keys to achieving this but necessitates cooperation from all sectors. The circular economy principles should be publicized to increase civil society awareness concerning community e-waste management. This will then drive the concept of practices for concrete outcomes. If every sector cooperates, it will result in a balanced economy under the vision of maximizing economic value and reducing the environmental and social impacts of production, consumption, waste management, and recycling.

Keywords

E-waste management, awareness, behaviors, circular economy, Bangkok

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Introduction

E-waste is being rapidly generated around the world. It has become one of the new threats to the environment due to technological advancement, the development of industry and economy, urban expansion, and population increase (Bhutta et al.., 2011; Needhidasan et al., 2014).

According to a survey by the Pollution Control Department (2021), the amount of e-waste worldwide is increasing continuously. In 2019, the amount of e-waste was up to 53.6 million metric tons worldwide and 421,335 tons in Thailand. Moreover, Thai e-waste increased by 435,187 tons in 2021, but only 22% could be managed (147,293.96 tons) out of the entire e-waste in Thailand (Pollution Control Department, 2022). Such management did not meet the goal set in the National Solid Waste Management Master Plan 2016-21 to manage e-waste properly according to the principle of collecting and disposing of at least 30% of community e-waste. Although the e-waste was appropriately managed according to the code, management was still insufficient (Tuntipalakul, 2016). Proper e-waste management is essential for reducing the adverse effects on health, the environment, and society. Improper e-waste management is partly from insufficient household e-waste separation from general waste due to a lack of knowledge and awareness in the public sector, as well as the lack of regulations directly related to e-waste management, separation, extraction, collection, and transport, and limitations in budget, places, and specialists for waste management.

In addition, the increase in e-waste quantity in Thailand results from government policies stimulating consumption, such as converting radio and television analog systems into digital and changing mobile phone frequencies (Kiddee & Bunmak, 2016). Therefore, people increasingly turn to using electrical appliances and electronic devices in line with government policies, increasing the number of unused devices and causing more e-waste. Such approaches become one factor causing e-waste to proliferate (Kitkerdsaeng, 2018). Moreover, many consumers prefer to have the latest model of electronic devices, and excessive consumption causes more e-waste (Mudju, 2017), such as mobile phone waste (Butsabok, 2013). Regarding e-waste management in the public sector, the government assigned local administrative organizations (LAO) and relevant agencies to arrange points for collecting hazardous waste in communities and then transferring them to the provincial waste collection centers (Department of Pollution Control, 2019). Although e-waste is managed correctly, such management is still inadequate (Tuntipalakul, 2016).

Bangkok is the capital city with, by far, the greatest population of residents and workers, so its e-waste is generated in higher quantities than in other provinces in Thailand. In addition, the Bangkok Metropolitan Administration (BMA) is a unique administrative organization with a single-level organizational system, meaning that BMA is the only organization responsible for all

of Bangkok (King Prajadhipok's Institute, n.d.) with authority and budget for e-waste management. Still, the BMA has yet to be successful in e-waste management. E-waste management problems usually occur from various factors, and communities are regarded as the primary sources of e-waste. As a result, diverse development has expanded in the communities in Bangkok. At present, the government sector has set a new Bio-Circular-Green (BCG) Economy Model as the national agenda for developing the economy holistically across three dimensions: (1) Bio-economy focuses on the full use of biological resources; (2) Circular economy focuses on reusing different materials as much as possible; and (3) Green Economy focuses on solving pollution problems and reducing the adverse effects on the Earth. Therefore, the researchers were interested in studying the awareness and behaviors of community e-waste management according to the circular economy in Bangkok to understand the public sector's cognition and behaviors of community e-waste management according to the circular economy. The circular economy is a sound system that is important for waste management. As current consumer behaviors overuse resources, the circular economy is the primary mechanism for driving the economy with an emphasis on zero waste and focusing on effective waste reuse, leading to long-term sustainable development for communities and the country.

Objectives of the Study

This research studied the awareness and behaviors of e-waste management in the public sector according to the circular economy.

In addition, the following two hypotheses were postulated to help validate and illuminate our results while enriching existing theories on e-waste management in the study area:

H1 Different perceptions about hazardous e-waste results in different awareness and behaviors of community e-waste management according to the circular economy.

H2 Knowledge of e-waste management according to the circular economy has a relationship with awareness and behaviors in the e-waste management according to the circular economy.

Literature Review

E-Waste Classification and Sources

E-waste or waste from electrical and electronic equipment (WEEE) refers to electrical and electronic equipment suffering from end-of-life, deterioration, or inability of use, such as mobile phones, televisions, computers, etc., except for reuse or recycling (Office of Natural Resources and Environmental Policy and Planning, 2020). According to the European Union Directive (2018/849), e-waste is classified into the following ten international-use categories (Table 1).

Table 1. Electronic Waste (e-waste) Categories

1	Large household appliances	Refrigerators, freezers, washing machines, clothes dryers, dishwashers, electric cooking stoves and hot plates, microwaves, electric fans, and air conditioners.
2	Small household appliances	Vacuum cleaners, toasters, grinders, coffee machines, appliances for haircutting and drying, toothbrushing, and shaving.
3	Information technology (IT) and telecommunications equipment	Mainframes, minicomputers, personal computers, laptops, notebooks, printers, telephones, and cell phones.
4	Consumer equipment	Radios, televisions, video cameras, video recorders, stereo recorders, audio amplifiers, and musical instruments.
5	Lighting equipment	Straight and compact fluorescent lamps and high-intensity discharge lamps.
6	Electrical and electronic tools	Drills, saws, sewing machines, soldering irons, equipment for turning, milling, grinding, drilling, making holes, folding, bending, or similar processing of wood and metal.
7	Toys, leisure equipment, and sporting goods	Electric trains or racing car sets, video games, and sports equipment with electric elements.
8	Medical devices	Radiotherapy equipment, cardiology, dialysis, pulmonary ventilators, nuclear medicines, and analyzers.
9	Monitoring and control instruments	Smoke detectors, heating regulators, and thermostats.
10	Automatic dispensers	For hot drinks, hot or cold bottles, solid products, money, and all appliances that automatically deliver various products.

Source: Gill, G. N. (2016)

In addition, E-waste generation has effects on the environment, such as toxic contamination in the air from e-waste due to improper burning of electronic devices. Such burning causes heavy metals such as lead, cadmium, mercury, etc., to become aerosols spreading in the air. Mercury may accumulate in the food chain, such as residue in aquatic animals, which can spread to humans when consuming contaminated animals. Moreover, current climate change can be partly caused by disposing of compressors of refrigerators and air-conditioners which contain refrigerants, especially in the older models. Waste disposal by burning or discarding refrigerants, particularly chlorofluorocarbon (CFC) compounds, can make substances evaporate into the atmosphere and destroy the ozone layer (Wittaya-Anumat, 2017; Phuphisut &

Sangrajang, 2010). There are adverse effects on health from various hazardous substances and heavy metals in e-waste. Heavy metals contaminate the environment, and lead is considered a heavy metal that is very harmful to humans and animals. The concern is for children under six years old living in the e-waste sorting areas. These children risk receiving high quantities of lead, resulting in lead poisoning.

Moreover, lead dust on parents' clothing can quickly spread to children through the respiratory system. Child behaviors in picking things up or putting hands into their mouths can cause a risk of ingesting lead through the gastrointestinal tract, and the bodies of young children can absorb contaminants through the gastrointestinal tract 4-5 times more easily than adults. Currently, no lead exposure levels are considered safe. As lead accumulates in young children's bodies, it can destroy their nervous system. The development of the brain and the central nervous system is affected by lead poisoning, causing children to have slow cognitive development, poor growth, and behavioral maladies such as attention deficit hyperactivity disorder (ADHD) and anemia (World Health Organization, 2014).

Circular Economy

Circular Economy is a concept for processing and recycling used resources with an emphasis on effectively using resources and solving overuse problems due to the expansion of the world population and waste management problems (Mahakan & et al., 2019). This is possible by retaining the value of raw materials, resources, and products for as long as possible or recovering them with minor damage (Ministry of Industry, 2016). The change is to use resources in the same direction in the form of a Linear Economy with the focus on changing the Take-Make-Dispose cycle into the Make-Use-Return cycle for growth with balance in the quality of life and sustainable future (TBCSD, 2020). Therefore, the concept can, in principle, be applied to all kinds of natural resources, including biotic and abiotic materials, water, and land. In the circular economy, eco-design, repair, reuse, refurbishment, remanufacture, product sharing, waste prevention, and waste recycling are all important (European Environment Agency, 2016). The concept has the goal of achieving sustainable development at the local, national, and international levels (Lacy P. & et al., 2014) by driving the 3Rs principle: 'reduce' for less use, use only as necessary, or less waste production; 'reuse' for repetitive use to expand product lifecycle and usefulness; and 'recycle' for processing waste with the 5Rs principle through repair and refurbishment, leading to value creation in the circular economy (Khaosa et al., 2009). Therefore, the circular economy is implemented with specific procedures and guidelines such as product eco-design, reuse, repair, and industrial connection (Chertow & Ehrenfeld, 2012; Lombardi & Laybour, 2012).

The circular economy is a logical system tailored to address problems of e-waste mismanagement due to consumer behaviors. This principle calls for product lifecycle

management by changing end-of-life products into usable resources through production or processing. It is expected to help reduce e-waste in Bangkok to become a "zero e-waste society" and promote long-term environment preservation, leading to vibrancy for Asia according to the 20-year Development Plan for the Bangkok Metropolis.

The circular economy principle focuses on the values of various things, including raw materials, resources, and products, to maintain them as long as possible and generate as little as possible or zero waste. The circular economy principle is based on three aspects (Pongruktham et al., 2020) as follows:

Principle 1: Preserve and optimize natural resource capital through management and control of limited natural resources by creating benefits or values of resources in every possible opportunity.

Principle 2: Maximize resource utilization through the circulation of products, parts, and different materials for maximum benefit through designing products for prolonged use; processing used resources; repairing or improving damaged or defective products which are returned to manufacturers to bring them back for sales again; maintaining materials and equipment to be always ready for use; repairing damaged items to function well again; reusing useful things; creating new products from used materials as raw materials for processing; process waste materials to be new things by adding beauty with new ideas to increase the value of things which are going to be waste.

Principle 3: Maintain system effectiveness through designing to avoid negative effects of products. This principle covers reducing adverse effects on the environment, economy, society, quality of life, values of uses, and management of adverse effects from resource utilization.

However, the circular economy principle has a mechanism based on the concepts of biomimicry or nature-imitating innovation, industrial ecology, and environmental design with thinking of process rather than products in the product life cycle from pre-production to post-use by basing on nature as a model (Pongruktham et al., 2020).

Perception

Perception is a determinant of communication, attitudes, and expectation, and it is a process of stimuli response and interpretation (Good et al., 1998). This stimuli response and interpretation process allow an individual to select, organize, and interpret various stimuli into meaning or impression. Two respondents with exposure to the same stimulus in the same context may differently memorize, select, organize, and interpret such stimulus, depending on internal factors of each person, such as personal needs, values, expectations, etc. (Schiffman & Kanuk, 2004). Information is perceived with attention and understanding at the exposure stage. The receiver perceives information through the senses, leading to the attention stage before sharing

an interest in that stimulus and then understanding its meaning at the final comprehension stage (Mowen & Minor, 1998).

Perception is the starting point of various behaviors. Although respondents perceive the same information from the same source, they may interpret it differently and behave differently. Regarding perception in e-waste management, the starting point relates to attitudes since personal perception affects behaviors. The present study investigated the behaviors and practices resulting from perceptions or attitudes toward e-waste management in communities. However, the influence on perception depends on each person's internal motivation and attitude, the content of the information, and the benefits that a person gets from the information through the perception process to the reaction to e-waste management.

Awareness and Behaviors

Awareness refers to reflective thinking about the necessity to do, agree, or be convinced before expressing in a practical form with responsibility for emerging problems (Good C. V. Merkel W. R. & Phi Delta Kappa., 1973) as the minimum level of emotion and feeling. Awareness is like knowledge, and both are not stimuli that are necessary to be a phenomenon or something else. Awareness occurs when there is a stimulus as an activating factor (Bloom et al., 1971). Awareness is comparable to consciousness as an individual's psychological status caused by knowledge and experience, with an assessment of the values and importance of these. It is an active psychological status activated by an incident or a situation. In other words, the period of experience and surrounding factors stimulate awareness (Koffka, 1978). The occurrence of awareness is a sudden realization, but it may not involve the ability to remember or recognize certain aspects (Namnakhon, 2007). According to Chalermklin (2008), however, awareness refers to responsible Behavior about something or some incident as an emotion or feeling about attitude, value, like or dislike, and good or bad from a person's assessment of that stimulus.

Awareness through sudden realization is something like a feeling. Sometimes, it is unidentifiable between awareness or a sudden emotion/feeling. The occurrence of awareness relies on external factors from surrounding matters. Therefore, awareness of e-waste management implicitly relies on external factors to manage e-waste with a perception of the continuous increase of e-waste. Awareness is always a subconscious perception divided into two aspects. The first aspect of awareness is from an external factor, which includes stimulus aspects that interest a person to perceive e-waste management, leading to awareness. The other aspect of awareness is from an internal factor, including personal characteristics. The level of a person's awareness depends on his/her physical and psychological characteristics. Therefore, both factors are significant sources of e-waste management awareness.

E-Waste Management According to the Circular Economy in Bangkok

The BMA currently has an environmental development plan for dealing with household e-waste. The BMA has been implemented in compliance with the government policy, which announced the solution of e-waste problems as the national agenda. For the e-waste amount in Bangkok, the BMA has set a policy for daily collecting and storing e-waste in all areas to prevent residual waste, and disposing of it in a sanitary way, as well as for building respondents' discipline by legislating regulations on inspection and imposing fines for cases of littering in public areas or illegally littering in a wasteland. In addition, the implementation is on building discipline and awareness of waste separation in schools by cultivating students' habits in reducing and separating waste and setting up a system of littering in classified waste bins. Respondents in all sectors are encouraged to participate in reducing and separating waste at its source and transfer it to the waste disposal center in a suitable way (Department of Environment, 2021). Waste management is divided into three parts as follows.

Part 1: E-waste disposal at the source is done to solve the increasing amount of e-waste by enhancing e-waste reduction and separation at its source and using it for full benefit with cooperation between all sectors of society. This approach to management is implemented according to the 3Rs. Firstly, 'reduce' aims to decrease using high-dangerous chemical products unable to be processed to prevent the production of electronic products with effects on the environment as well as to prevent e-waste from these products when they are no longer used to affect the environment in communities. Secondly, 'reuse' aims to fix or repair some damaged electronic equipment or reuse some electronic parts without repairs. Lastly, 'recycle' aims to transform product waste by reusing it by reproducing valuable resources from product waste. Such implementation is at the heart of the circular economy.

Part 2: E-waste disposal at the midway point is the daily management of e-waste in Bangkok and deploying e-waste collection trucks by BMA for every district to thoroughly collect and transfer e-waste to the disposal system. E-waste is collected every 15 days or as specified by the district office.

Part 3: E-waste disposal at destinations collects e-waste from all 50 districts, and transports these to the three BMA waste disposal centers, including On-Nut Disposal Plant, Nong Kham Garbage Disposal Plant, and Sai Mai Garbage Disposal Plant. Moreover, the BMA has hired a private contractor to dispose of e-waste properly.

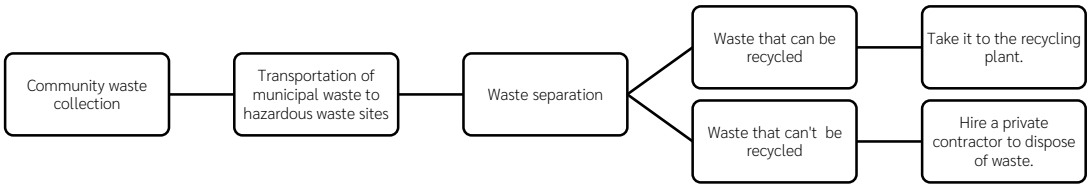

Figure 1. Summary of e-waste Management Process by the Department of Environment of the BMA

Source: Department of Environment (2021)

The above guidelines for e-waste management (Figure 1) are for implementation to solve e-waste problems in Bangkok. According to the study on the situation and issues of e-waste management in the communities of Bangkok, the BMA still faces a formidable challenge to manage the enormous volume of e-waste that grows daily. E-waste is not entered into the proper e-waste management system, causing residual, bulky waste. Moreover, people's behaviors also lead to e-waste management problems in most communities. Wasteful product consumption is a response to company advertisements and promotions and with minor technological advancements to encourage new purchases.

Apart from e-waste management under the control of the Environment Department, the BMA also cooperates with the public sector in product recall or e-waste disposal services, such as educating consumers about how to exchange electrical appliances or electronic devices or to make them more valuable. Advance Info Service Public Company Limited, or AIS, arranges a trade-in promotion by returning old mobile phones to get discounts on buying new ones. Moreover, under the Project "Thai People with Zero E-waste," AIS wants to publicize by focusing on awareness of e-waste danger and understanding correct e-waste disposal by processing or destroying properly (Advanced Info Service Public Company Limited, 2021).

The Study Area

This study carried out a survey in Bangkok, the capital of Thailand, which falls under the responsibility of the BMA. The BMA is a unique local government organization distinctive from other provinces in Thailand. It is responsible for an area of 1,570.61 sq km in total (Department of Strategy and Evaluation, 2012B) divided into 50 districts in 6 zones to increase the effectiveness of urban development (Department of Strategy and Evaluation, 2012A), as shown in Figure 2.

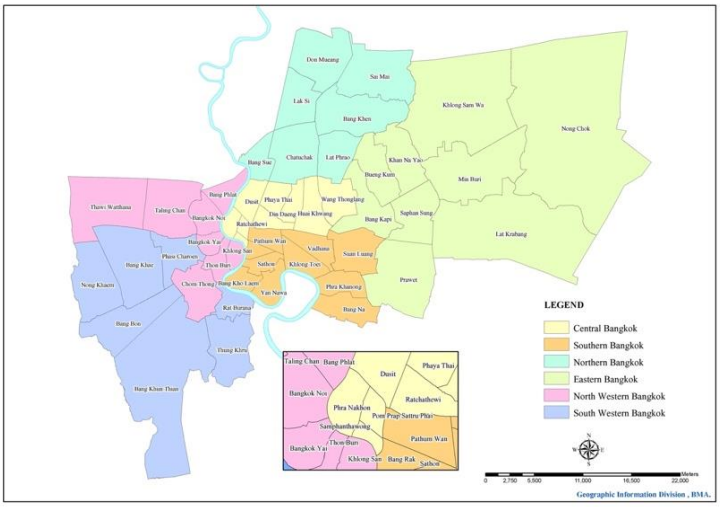

Figure 2. Map of the 50 Districts of Bangkok by Zone

Source: Bangkok GIS Center (2021)

Phra Nakhon Zone

1) Central Bangkok includes the districts of Phra Nakhon, Dusit, Pom Prap Sattruphai, Samphanthawong, Din Daeng, Huai Khwang, Phaya Thai, Ratchathewi, and Wang Thong Lang.

2) South Bangkok includes the districts of Pathum Wan, Bang Rak, Sa Thon, Bang Kho Lam, Yan Nawa, Khlong Toei, Watthana, Phra Khanong, Suan Luang, and Bang Na.

3) North Bangkok includes the districts of Chatuchak, Bang Sue, Lat Phrao, Lak Si, Don Muang, Sai Mai, and Bang Khen.

4) East Bangkok includes the districts of Bang Kapi, Saphan Suang, Bueng Kum, Khanna Yao, Lat Kra Bang, Min Buri, Nong Chok, Khlong Sam Wa, and Prawet.

Thon Buri Zone

5) North Thon Buri includes the districts of Thon Buri, Khlong San, Chom Thong, Bangkok Yai, Bangkok Noi, Bang Phlat, Taling Chan, and Thawi Watthana.

6) South Thon Buri includes the districts of Pasi Charoen, Bang Khae, Nong Kham, Bang Khun Thien, Bang Bon, Rat Burana, and Thung Khru.

The management of the environment and waste, including e-waste, falls under the Department of Environment, BMA. The guidelines for e-waste management are specified as a part of the 20-year Development Plan for the Bangkok Metropolis 2013-32, with the vision of "Emphasising waste management at the source, with the participation of all sectors according to the concept of zero waste management" (Department of Environment, 2020). The BMA has set the 20-year vision to be the "Vibrancy of Asia" (Department of Strategy and Evaluation,

2012B) to drive the economy and society as the leading city in the economy, services, safety, beauty, convenience, pleasant living, and environmental friendliness.

Research Methodology

Study Design and Population

This study utilized quantitative approaches to data collection and analysis. The framework of this study was on guidelines for community e-waste management according to the circular economy principle in Bangkok. The study reviewed the literature from secondary data in books, academic papers, related research, and internet information and then synthesized the data into a questionnaire for collecting primary data. Understanding e-waste and the circular economy principle in the public sector and perception of e-waste management will lead to awareness and behavior in community e-waste management according to the circular economy in the public sector. The independent and dependent variables are presented in Figure 3.

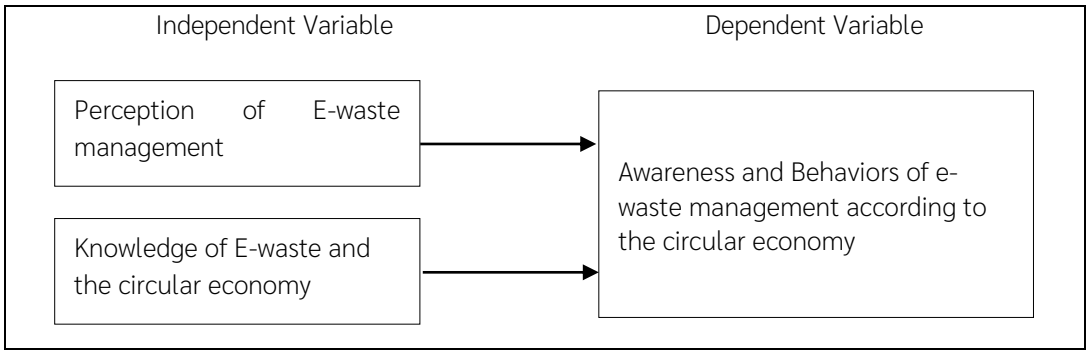

Figure 3. The framework of this study

Awareness and Behavior in community e-waste management according to the public sector's circular economy are essential for analyzing problems and obstacles in community e-waste management and for proposing a suitable model and guidelines to address deficiencies.

This study was a cross-sectional study carried out between May – October 2021, employing quantitative data collection methods. Informed consent was obtained from respondents aged 18 years or older residing and working in Bangkok for at least one year before the data collection. We used multistage sampling to select 480 respondents who worked and lived in Bangkok. The sample size was calculated using the Krejcie & Morgan (1970) formula for cross-sectional studies. We considered the following assumptions: a 95% confidence interval (1.96), prevalence, p as 50%, precision, α = 5%, and a non-response rate of 20%.

For the quantitative survey, we used a multistage sampling technique. Quota sampling was used to recruit 240 respondents for each group. The first group represents the diversity of demographic aspects in different places in Bangkok whereas, in the second group, sample selection was stratified by the 50 districts in six administrative zones. Simple random sampling was used to obtain the sample respondents. Next, the lot drawing method was used to select the district to be representative of each administrative zone. The researchers drew lots to choose two districts from one administrative area. Therefore, the study included 12 districts in six zones. Both groups were selected to include diverse demographic characteristics while being geographically distributed throughout Bangkok. A structured questionnaire was used to collect data, which consisted of the following five parts:

Part 1 Demographic and socio-economic characteristics

Part 2 Perception of e-waste Management

Part 3 Knowledge of e-waste and circular economy

Part 4 Awareness of e-waste management according to the circular economy

Part 5 Behaviors of e-waste management according to the circular economy

Completing the questionnaire took about 10-20 minutes. Respondents' information was securely stored on a computer. A numeric code was assigned to access the information for security purposes. As for the study results report, the informant's identity was concealed.

Data Management and Analysis

Primary data were stored in Microsoft Excel (Microsoft 365) for further processing and coding. Subsequently, the data were subjected to inferential statistical analyses using SPSS and Stata 16 (StataCorp., 2019). Stata Statistical Software: Release 16. College Station, TX: StataCorp LLC, was used for cleaning and analysis. The hypotheses were subjected to t-tests, analysis of variance (ANOVA), and Pearson Product Moment Correlation. A probability level of 0.05 or less ($p < 0.05$) was considered statistically significant.

Ethical Approval

The protocol for this study was approved by the Ethics Committee in Human Research, of the National Institute of Development Administration, Bangkok, Thailand (Certificate of approval no. ECNIDA 2021/0047), and complies with the Declaration of Helsinki guidelines. We obtained written informed consent from all participants, and data were treated with maximum confidentiality by storage in password-protected computers only accessed by the research supervisor and principal investigator.

Results

Demographic and Socio-economic Characteristics of the Respondents

The sample of 480 respondents was half male (50.8%) and half female (49.2%). Most of the respondents were between the ages of 21 and 30 years (55.0%), followed by ages 31 to 40 years (17.1%) and ages 41 to 50 years (12.7%). Only a few respondents were between 51 and 60 years (2.0%). Regarding education, most of the sample had graduated at the bachelor's degree level (58.5%), followed by the postgraduate level (32.7%) and high school diploma or vocational certificate (3.8%). Three respondents had completed only primary education (0.6%).

According to the socio-economic characteristics, the largest percentage were civil servants (27.1%), followed by office workers (26.3%). A small number were state enterprise employees (6.3%). There were similar numbers of students (9.4%), other occupations (freelancers, traders) (10.2%), and entrepreneurs (11.0%).

For monthly income, most respondents earned between 15,001- 30,000 baht (44.8%), followed by 15,000 baht or less (26.5%). There were similar proportions earning 30,001-45,000 baht per month, more than 60,000 baht, and 45,001- 60,000 (9.4%, 9.6%, and 9.8%, respectively).

More than half of the sample had lived in Bangkok for at least ten years (57.1%), followed by less than six years (32.1%), and six to ten years (10.8%). Most respondents in this sample lived in south Bangkok (29.0%). A longer duration of living in Bangkok might indicate greater knowledge about e-waste management in their home neighborhood. That said, the respondents improperly disposed of an average of 1.3 pieces of e-waste per month (S.D. 1.1).

Perception of E-waste Management

More than three out of five respondents were familiar with the concept of e-waste management (62.7%). Figure 4 presents the results for learning sources on e-waste management of the respondents in Bangkok. More than half got information about e-waste management through online social media (53.1%), followed by smartphones (38.8%), and through friends or relatives (6.5%). On the other hand, the proportion of respondents without information about e-waste management was relatively high (37.3%), indicating that the perception of e-waste management in the study area was low.

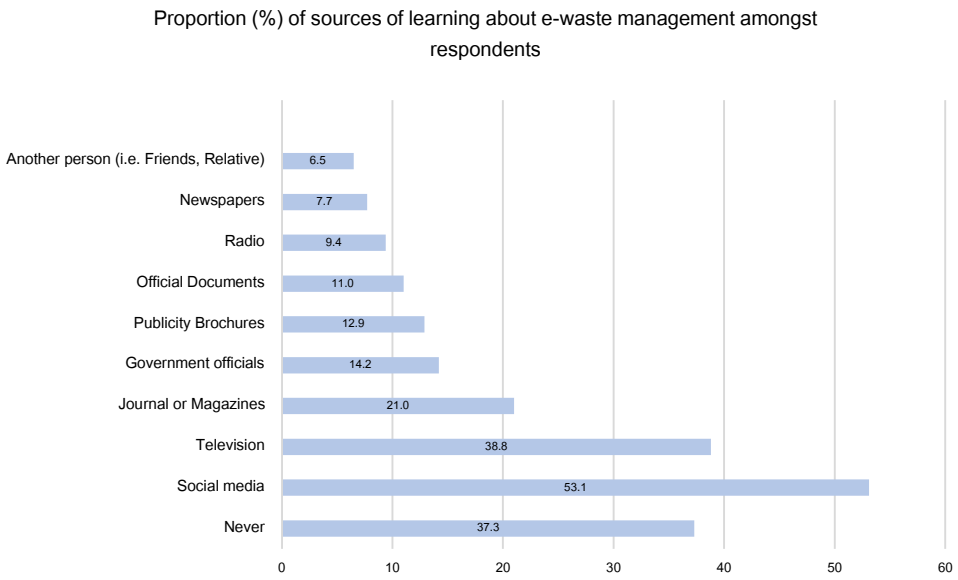

Figure 4. Sources of Awareness about e-waste Management

Knowledge of E-waste and Circular Economy

Table 4 shows statements estimating knowledge of e-waste amongst respondents. The vast majority of respondents knew the definition of e-waste (Item 1) (88.5%). There was very high knowledge about the problems and effects of e-waste (Item 4) (94.2%), followed by e-waste disposal methods '*repairing damaged electrical appliances to be used can reduce the amount of household e-waste*' (Item 8) (92.7%). However, a quarter of the respondents could not correctly answer the statement in Item 3 ('*e-waste problems have adverse effects on humans')*. The average knowledge score for the respondents on e-waste was 6.8 out of a maximum score of 8.0.

Table 4. Percent Disagreeing/Agreeing with Statements Reflecting Knowledge of e-waste (n = 480)

Statements Estimating E-Waste Knowledge	No	Yes
E-waste means broken or obsolete electrical and electronic equipment	11.5	88.5
E-waste is toxic to households	18.5	81.5
E-waste problems have adverse effects on humans, but no effects on the environment	71.3	28.7
Toxic substances in e-waste negatively affect humans	5.8	94.2
Burning is the most suitable method for disposing e-waste	72.3	27.7
Using electrical appliances only as necessary can reduce the amount of household e-waste	14.3	85.7

Table 4. Percent Disagreeing/Agreeing with Statements Reflecting Knowledge of e-waste (n = 480) (Cont.)

Statements Estimating E-Waste Knowledge	No	Yes
Components of e-waste come from heavy metals such as lead, cadmium, mercury, etc.	10.6	89.4
Repairing damaged electrical appliances for reuse can reduce the amount of household e-waste	7.3	92.7

Note: The correct response is in bold type

Table 5 shows statements reflecting knowledge of the circular economy among respondents. Most knew the definition of the circular economy (Item 1) (81.9%), as well as the Sufficiency Economy philosophy for the development of societies, the economy, and the environment (Item 2) (79.0%). In principle, most of them knew that the circular economy emphasizes the highest effectiveness of resource use (Item 4) (87.1%); the circular economy emphasizes use according to the 5Rs principle 5Rs (Reduce, Reuse, Recycle, Renewable, and Refuse) (Item 8) (86.5%); and application of the circular economy can help reduce e-waste problems (Item 5) (80.4%). The average score for correct knowledge of the circular economy principle was 6.8 (out of a maximum possible total of 8.0).

Table 5. Percent Disagreeing/Agreeing with Statements Reflecting Knowledge of the Circular Economy (n = 480)

Statements Estimating Circular Economy	No	Yes
The circular economy is a strategy for returning the resources used in production and consumption to the production process.	18.1	81.9
The circular economy conforms to the sufficiency economy philosophy for the development of the society, economy, and environment.	21.0	79.0
The circular economy is a strategy for environmentally-friendly products.	18.8	81.3
The circular economy emphasizes the highest effectiveness of resource use.	12.9	87.1
The application of the circular economy can provide results for solving e-waste problems.	19.6	80.4
The preservation of natural resources is a part of the circular economy.	23.8	76.3
The production of electrical appliances by focusing on using the least amount of natural resources with the fullest benefits is a practice according to the circular economy.	25.4	74.6
The circular economy emphasizes use according to the 5Rs principle 5Rs (Reduce, Reuse, Recycle, Renewable, and Refuse).	13.5	86.5

Note: The correct response is in bold type

Overall, the respondents knew the basic concepts of e-waste (85.2%) and circular economy (77.1%) at a high level.

Awareness of E-waste Management

Table 6 presents the respondents' awareness of e-waste management according to the circular economy. Most of the respondents were aware of problems in e-waste management according to the circular economy. They were aware that '*e-waste should not be burned since it causes air pollution* (Item 1) (92.3%), followed by '*e-waste disposal with a correct processing method is the good way to reduce e-waste amount*' (Item 5) (87.7%), and the same proportion knowing that '*repairing damaged electrical equipment or appliances to be reusable as long as possible can reduce e-waste amount*' (Item 6) (87.7%), and '*using electrical and electronic equipment only as necessary is regarded as avoidance of using hazardous products*' (Item 7) (83.8%). In addition, three-quarters of the respondents were aware that '*consumption of electrical appliances without green labels can adversely affect health and environment*' (Item 3) (75.0%).

However, regarding Item 2 ('*e-waste landfill is the best management method*'), more than half of the respondents answered 'yes' (56.9%), which is incorrect.

Table 6. Percent of Respondents Disagreeing/Agreeing with Statements about e-waste Management According to the Circular Economy Principle (N = 480)

Awareness of e-waste management according to the circular economy	No	Yes
E-waste should not be burned since it causes air pollution	7.7	92.3
E-waste landfill is the best management method	43.1	56.9
Consumption of electrical appliances without green labels can affect health and the environment	25.0	75.0
Inability to dispose of e-waste can have negative effects on the national economy and societies.	25.6	74.4
E-waste disposal using an appropriate processing method is a good way to reduce the amount of e-waste	12.3	87.7
Repairing damaged electrical equipment or appliances to be reusable as long as possible can reduce the amount of e-waste	12.3	87.7
Using electrical and electronic equipment only as necessary is regarded as avoiding the use of hazardous products	16.3	83.8
Using electrical and electronic equipment that is not in trend is one way to reduce sources of e-waste	33.8	66.3

Note: The correct response is in bold type

Most of the respondents (70.6%) in this sample were aware of e-waste management according to the circular economy at a high level.

Table 7. Behaviors of e-waste Management According to the Circular Economy (%)

Behaviors of e-waste management in the residential area according to the circular economy	Always	Seldom	Never
Reduction of amount of e-waste			
Buy electrical and electronic equipment by mainly considering quality and lifetime	80.6	19.4	0.0
Regularly take care of and maintain electrical and electronic equipment	72.3	27.7	0.0
Reuse of e-waste			
Take broken electrical and/or electronic equipment to be repaired at a service center	71.9	26.0	2.1
Trade in electrical and/or electronic equipment for a new one	35.0	43.5	21.5
Selection to use electrical and electronic equipment			
Buy electrical and electronic equipment with energy-saving and environmentally friendly labels	82.5	17.5	0.0
Buy electrical and electronic equipment which is necessary for daily use	83.5	15.6	0.8
E-waste separation			
Separate recyclable parts such as copper and circuit boards from electrical and electronic equipment	30.4	26.5	43.1
Separate e-waste from general solid waste before taking it out	64.6	26.5	9.0
Waste storage in suitable containers			
Put e-waste in a bag with an e-waste label for staff to see clearly before taking it out	54.6	27.9	17.5
Take out e-waste at a specific point waiting for collection by staff	50.6	32.1	17.3
E-waste disposal			
Take end-of-life electrical and electronic equipment to deposit at collection points arranged by the district office or village center	53.5	22.9	23.5
Take end-of-life electrical and electronic equipment to a disposal service center or agency to collect and dispose of it	50.6	24.8	24.6

Table 7 presents the behaviors of e-waste management in residential areas according to the circular economy. To reduce the amount of e-waste, most respondents buy electrical and electronic equipment by mainly considering quality and lifetime (80.6%). Most respondents (71.9%) brought broken electrical and electronic equipment to be repaired at a service center. Most respondents (83.5%) chose to buy electrical and electronic equipment only as necessary for daily use. Over three in five respondents (64.6%) separated e-waste from general solid waste before disposing. For waste storage in suitable containers, slightly more than half the sample (54.6%) put e-waste in a bag with e-waste labels for collection personnel to see before taking it out for disposal. A similar proportion (53.5%) took end-of-life electrical and/or electronic equipment to the collection points arranged by the district office or village center.

Overall, most of the respondents (76.5%) had behaviors regarding e-waste management that are highly consistent with the principles of the circular economy.

Most of the respondents (70.6%) in this sample were aware of the importance of e-waste management according to the circular economy.

For the perception variable, the study used the *t*-test to compare the mean score difference between two independent groups on awareness and behaviors of e-waste management in residential areas according to the circular economy to test Hypothesis 1 (H1). The results are shown in Table 8.

Table 8. Results of *t-test of* the Perception Variable on Awareness and Behaviors of e-waste Management in Residential Areas According to the Circular Economy

	Perception	N	Mean $\pm$ S.D.	*t*	*p*-value
Awareness	perceive	301	6.52 $\pm$ 1.53	6.304	<0.001*
	don't perceive	179	5.41 $\pm$ 2.03		
Behaviors	perceive	301	19.22 $\pm$ 4.22	8.991	<0.001*
	don't perceive	179	15.16 $\pm$ 5.09		

Note: N: Number of respondents; *P-value: Significant at $p < 0.05$ level

In the relationship analysis between the predisposing factors (knowledge of e-waste) and the reinforcing factors (perception about e-waste management) on awareness and behaviors in residential areas according to the circular economy in Bangkok, the Pearson product-moment correlation coefficient was applied to test Hypothesis 2 (H2). The results are shown in Tables 9 and 10.

Table 9. Pearson's Correlation Coefficients on Awareness in Residential Areas According to the Circular Economy in Bangkok

Variables	N	*r*	*p*-value
The predisposing factors			
knowledge of e-waste	480	0.46	<0.001**
knowledge of circular economy	480	0.44	<0.001**
The reinforcing factors			
perception about e-waste management	480	0.30	<0.001**

Note: N: Number of respondents; r: Correlation Coefficient; **P-value: Significant at p < 0.01 level.

Table 10. Pearson's Correlation Coefficients on Behaviors in Residential Areas According to the Circular Economy in Bangkok

Variables	N	*r*	*p*-value
The predisposing factors			
knowledge of e-waste	480	0.02	0.617
knowledge of circular economy	480	0.20	<0.001**
The reinforcing factors			
perception about e-waste management	480	0.40	<0.001**

Note: N: Number of respondents; r: Correlation Coefficient; **P-value: Significant at p < 0.01 level.

Discussion and Conclusions

Community e-waste management in Bangkok currently faces a large quantity of e-waste, which increases yearly, apparently due to a lack of knowledge and understanding about e-waste. Therefore, the government sector is focusing on public information dissemination. However, according to the respondents in this survey, people had a high knowledge and understanding of e-waste (85%). Still, government facilitation in e-waste management was low (59%). It was also found that most people need a better understanding that e-waste is harmful and must be appropriately managed. The behavior of Thai society today is rather consumerist in that people too eagerly dispose of full-functional electronic devices simply to have the latest model or innovation. They too readily dispose of e-waste without considering the device's value, sorting, and reusing. The government sector requires a complete system to manage end-of-life electrical and electronic appliances. For example, the product recall system is still rare by product manufacturers and distributors. As a result, e-waste has become a growing burden for the BMA. The BMA does not have enough disposal areas with proper standards and management systems for e-waste collection, sorting or disassembly, transport, processing, and disposal.

Moreover, Thai law is only a comparative law, not a specific law. This conforms to the study on e-waste management methods by Butsabok (2013). According to that study, relevant agencies should arrange activities to promote awareness and values for people, especially youth,

to participate more as influencers to change norms through social media and, where possible, mass media. Moreover, manufacturers of electronic products should educate the public about the danger of e-waste and cooperate with the BMA in e-waste management. In another study, Jannuwat (2017) proposed a long-term measure by enacting laws specifically to enforce e-waste management, requiring centers for e-waste management in every district of the city, and mandating appropriate guidelines for e-waste recycling or reuse.

Presently, the guidelines for developing the bioeconomy, the circular economy, and the green economy are accepted as modern management principles. In Thailand, the BMA should apply these guidelines in the context of the nation's capital to properly manage e-waste with maximum benefit and effectiveness by focusing on the 3Rs principles of e-waste management: *Reduce, Reuse, and Recycle*. That would be a good starting point for implementing e-waste management according to the BCG model in the circular economy principle. However, to be successful, there would have to be acceptance of the system according to the value chain principle. Even today, there remain too many problems and obstacles in adopting the circular economy principle. Although the BMA 20-year Development Plan for 2013-32 describes the vision of "*Emphasising waste management at the source with the participation of all sectors according to the concept of zero waste*," the circular economy is not applied in practice. The problems and obstacles in using the circular economy principle can be summarized as follows:

1. In Thailand today (and Bangkok in particular), the society has adopted the norms and culture of a consumerist society, which encourages people to dispose of waste without sorting. This is a major factor behind discarding electronic devices after new models come out and not disposing of e-waste properly.

2. There are limitations in Thai laws and regulations for overall e-waste management. Currently, there are no specific acts or regulations for managing end-of-life electrical and electronic products.

3. There are cost limitations in environmental and social capital due to the development of e-waste management. Without a suitable model, e-waste management development according to the circular economy principle can adversely affect the structures of society and the environment.

According to this survey on awareness and behaviors of e-waste management in residential areas in Bangkok in the context of the circular economy, different demographic characteristics result in varying levels of e-waste knowledge. There were gender differences in knowledge scores between males (6.9 ± 1.3) and females (6.6 ± 1.6); significant differences ($p < 0.05$) in educational level and average income. In addition, different age results in varying levels of awareness concerning e-waste management according to the circular economy, which was statistically significant at $p<0.01$. By contrast, according to the circular economy, different

occupations also result in other behaviors of e-waste management in residential areas at a statistical significance of $p< 0.05$.

Different perceptions about hazardous e-waste result in varying awareness and behaviors of e-waste management in residential areas in Bangkok according to the circular economy at a statistical significance of $p <.05$. This finding conforms to H1 that 'different perceptions about hazardous e-waste result in varying awareness and behaviors of community e-waste management according to the circular economy.'

Regarding the relationship between the predisposing factors (knowledge of e-waste and circular economy) and the reinforcing factors (perceptions about e-waste management) on awareness and behaviors of e-waste management in residential areas in Bangkok according to the circular economy, the findings of this study do not conform to H2 'knowledge of e-waste management according to the circular economy has a relationship with awareness and behaviors in e-waste management according to the circular economy. That was because knowledge of e-waste did not correlate with behaviors of e-waste management in residential areas in Bangkok according to the circular economy.

In conclusion, community e-waste management, according to the circular economy in Bangkok, relies on collaboration from all sectors, including the government, private, and public sectors. In particular, administrators need to set clear directions in terms of policies, measures, and strategies for solving community e-waste problems. This finding is consistent with the studies of Mudju (2017) and Subongkot (2019), which state that the government sector should prepare readiness for e-waste management. Environmental management should also be the responsibility of manufacturers, who should see the economic value of managing e-waste more systematically. Manufacturers should be responsible for their products when these products are no longer usable. This principle is helpful for manufacturers to develop and improve products to be environmentally friendly to reduce the cost of waste disposal, including waste collection, sorting, and removal in the proper way. According to the study of Duangkaew & Leknoi (2021), a positive perception of the circular economy principle should be created and pushed as an advocacy mechanism. Personnel at the policy and program levels need to take the lead in promoting a new paradigm of how society views electronic devices. Correct knowledge and understanding of concepts are necessary for implementing the circular economy principle. In other words, the principle in implementing the circular economic system is a production process.

The ideal situation would be active collaboration between the government, the private sector, and the public. In that case, the implementation according to the model will be balanced in all aspects under the vision to obtain the highest economic value added, and to reduce adverse effects on society and the environment, ranging from production and consumption to waste disposal, reuse, and/or recycling. This is a part of moving towards a "Vibrant Asia," as targeted in the Bangkok Development Plan.

Recommendations

According to the findings from this study, the researchers offer the following recommendations:

1. Awareness and good behaviors of e-waste management should be enhanced through participation or public relations practically and concretely. The government sector should create new, enticing, and exciting advertising media, and enable access for the public at all levels to educate them on how to manage e-waste correctly. The goal should be to create a social norm of good e-waste management behaviors. Social media should be used to reach those who are most heavily dependent on electronic devices and who could be influencers to spearhead change in the circular economy approach.

2. More channels and avenues should be added to collect waste from electrical and electronic equipment. For example, people may return product waste to dealers or take it to collection points specified by the BMA. E-waste can create a market niche for middlemen vendors to buy household e-waste for repurposing or re-sale. Convenient channels should be added for collecting product waste, and gaps should be narrowed for disposing of e-waste correctly.

3. Regulations about e-waste management should be legislated and enforced quickly and concretely. The authorities should monitor compliance with e-waste practices in everyday life, and work to prevent improper e-waste management by second-hand shops and market stalls.

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