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Research Article

Government Support and Local Residents' Behavior in E-waste Management: Evidence from Thailand

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Abstract

Electronic waste (e-waste) management is a critical global pollution concern. This study investigates government support; local residents' perceptions, knowledge, attitudes, and behaviors related to e-waste management; and collaborative governance in southern Thailand. Employing both quantitative and qualitative methods, this research involves expert government officers who are well versed in e-waste management and local residents. The study utilized in-depth interviews, questionnaires, and workshops. The results revealed that the government is responsible for four e-waste management approaches, encompassing various e-waste collection, transportation, and disposal methods. Local residents exhibited low perceptions of e-waste news but possessed substantial knowledge and positive attitudes toward e-waste management. Surprisingly, general characteristics do not significantly influence e-waste management behavior. A statistically significant connection was found between perceptions (B = 0.065, t = 6.657, p value = 0.000) and attitudes (B = 0.079, t = 4.350, p value = 0.000) toward e-waste management, which had a positive relationship with e-waste management behavior in southern Thailand (p value < 0.01). Repairing appliances is the most common action taken (44.5%). Despite longer lifespans for electronic appliances than they did a decade ago, revisions to the draft waste electrical and electronic equipment Act are underway, aiming to incorporate stakeholder involvement and the extended producer responsibility principle. This study provides valuable insights into government and local community concerns regarding e-waste management and evaluates the efficacy of recent management procedures. These findings can inform the development of action plans that consider crucial aspects of e-waste management.

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Introduction

The management of electronic waste (e-waste) or waste electrical and electronic equipment (WEEE) has emerged as a critical global pollution issue [1–3]. Rapid technological development to meet human needs and comfort has led to a surge in the production of high-quality electric and electronic equipment (EEE) among countries controlling both technology and the market. However, this has resulted in a shift toward short-term utilization and a decline in long-term appliance usage through repair processes, leading to increased e-waste generation. In 2019, e-waste production reached 53.6 million metric tons (Mt) worldwide, but only 17.4% of e-waste was collected and recycled [4]. The annual increase in e-waste amounts to 3–5% [3]. E-waste differs from household hazardous waste in that it contains recyclable materials such as plastic and glass and valuable elements such as gold, silver, platinum, copper, palladium, aluminum and iron [5]. However, it also contains hazardous heavy metals such as lead cadmium and mercury, as well as persistent organic pollutants (POPs), including brominated flame retardants (BFRs), dioxin-like poly-

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chlorinated biphenyls (DL-PCBs), polybrominated diphenyl ethers (PBDEs) and poly-chlorinated biphenyls (PCBs), which cause environmental and health problems [6–7]. The concentration of these substances in the human body can have harmful effects on the brain, joints, kidneys, nervous system, reproductive system, skeleton, and thyroid [8]. E-waste is composed of both valuable materials and toxic substances, which can be recovered and reused through specific infrastructure and recycling technologies. However, improper recycling techniques pose health risks and contribute to air, soil, surface, and ground-water pollution, resulting in long-lasting environmental hazards [9–10]. In Thailand, electronic appliances such as televisions, refrigerators, washing machines, vacuum cleaners, computers, and mobile phones, which cannot be repaired, are commonly found in hazardous waste. Approximately 65% of household hazardous waste in Thailand is e-waste, with 435,187 tons produced in 2021 [11]. Moreover, the current situation of improper e-waste recycling has concentrated on e-waste recycling communities in the northeastern region [12]. Moreover, it has also dispersed through informal recycling activities at junk shops across the country, especially in the southern region, where contamination of lead in the soil around junk shops engaging in e-waste recycling activities has been detected at high levels [13–14]. The widespread issue of informal e-waste recycling behind junk shops presents a significant environmental concern, as these pollution sources are often located near residential communities. Consequently, this is a critical issue that requires urgent attention and action. Therefore, addressing the growing e-waste problem necessitates the establishment of collection and recycling centers globally [15], along with the implementation of e-waste regulations involving all stakeholders. Currently, more than 78 countries have already implemented specific laws and regulations for e-waste management [4]. Addressing the complex issue of e-waste management requires the consideration of various factors, including understanding, attitudes, behaviors, socioeconomic conditions, and the roles of local governments and communities [16–19]. One of the significant challenges in managing e-waste in Thailand is the disconnect between government support and the perceptions, knowledge, attitudes, and behaviors of local residents. The incorporation of local perspectives fosters community engagement and a sense of ownership in waste management efforts. By acknowledging and integrating community beliefs and practices, sustainable solutions can be collaboratively developed with residents [20]. Household knowledge is crucial in shaping waste management strategies and behaviors. Effective approaches should include policies and practices aimed at reducing environmental risks, alongside educational initiatives that raise awareness about health concerns and proper waste disposal [21]. Additionally, factors such as attitudes, subjective norms, and perceived behavioral control play a significant role in influencing e-waste recycling intentions and behaviors [22].

Therefore, this study aims to investigate government support and the perceptions, knowledge, attitudes, and behaviors of local residents in e-waste management, as well as collaborative governance among the government, private sector and local residents in southern Thailand. The findings provide important information for the relevant sections, including governmental sectors, from the central control level to the local level, to facilitate appropriate decision-making regarding e-waste management. This research also supports further studies in relevant fields for the whole country.

Materials and methods

The study area is the southern region of Thailand, which consists of 14 provinces: Krabi, Chumphon, Trang, Nakhon Si Thammarat, Narathiwat, Pattani, Phang Nga, Phatthalung, Phuket, Yala, Ranong, Songkhla, Satun, and Surat Thani. The southern region is located on the Malay Peninsula, bordered by the Gulf of Thailand to the east and the Andaman Sea to the west, covering 73,848 km^2. This study involved both quantitative and qualitative analyses. The study was divided into three parts: Part 1 focused on the government, and document research and in-depth interviews were conducted. Part 2 involved questionnaire interviews with local residents. Part 3 explored collaborative governance among the government, private sector and local residents in terms of e-waste management. This study was conducted from March 2021 to February 2022. The Ethics Committee of the Institute of Research and Development at Thaksin University approved this research (COA No. TSU 2021-037 REC No.0019). The details of each analysis are described below.

1) Assessment of government officers' concerns regarding the management of e-waste

This study investigates e-waste management by the government in 14 provinces of southern Thailand. The secondary data were reviewed from articles, government reports (such as those from the Pollution Control Department and the Center of Excellence on Hazardous Substance Management), and strategic plans (such as the Integrated Management Strategy for Waste Electrical and Electronic Equipment by the Pollution Control Department [23]). In addition, in-depth interviews with government officers were conducted. A specific group of government officers who are experts in the field and who have sufficient knowledge concerning the management of e-waste and who have the power to operate relevant regulations were interviewed. These individuals represented 5 government sectors: 1) the Provincial Administrative Organization; 2) the Provincial Office of Natural Resources; 3) the Provincial Public Health Office;

4) the Provincial Office for Local Administration; and 5) the Provincial Industrial Office. The officers from all southern regions subsequently interviewed 70 people. The questionnaire was a tool for structured interviews. The questionnaire addressed four issues related to e-waste management: 1) recent problems; 2) recent solutions; 3) guidelines for problem solving; and 4) trends regarding future regulations for remedies. In the questionnaire data analysis, the data were systematically sorted by similarities concerning each issue and grouped by the relationships among such similarities. The interviews were conducted by a researcher to minimize data bias. Furthermore, data accuracy and reliability are verified through various contextual checks, such as traingulation and consistency checks, to validate the information.

2) Assessment of local residents' perceptions, knowledge, attitudes and behaviors toward the management of e-waste

The study focused on a sample group residing in the southern region with a population of 9,493,757 people (Population Statistics, March 2021). The sample size was calculated via Yamane's method [24] with a confidence level of 95%. A sample of 1,600 residents from the entire southern region, comprising 14 provinces, with the number of questionnaires distributed in each province proportional to the population ratio. Data were collected from both face–to–face interviews with 596 participants and online responses via Google Forms with 1,004 participants. The surveys were conducted by the research team, who was trained to understand the objectives of the study and the questions in the questionnaire before the data were collected. The questionnaires were randomly selected. The participants were aged 18 years or older and had lived in the southern region for more than a year. Informed consent for participation in the interviews was obtained from the interviewees through the first page of the questionnaire, whether the interviews were conducted face-to-face or online via Google Forms. The questionnaire was developed on the basis of the literature, including articles, and was designed following a specific research framework focusing on perceptions, knowledge, attitudes, and behaviors related to e-waste management. The questionnaire consisted of 6 sections, including 1) general characteristics of the questionnaire respondents; 2) perceptions of news regarding the management of e-waste; 3) knowledge concerning e-waste management; 4) attitudes toward e-waste management; 5) behaviors related to disposing and managing e-waste; and 6) suggestions concerning government regulations that can motivate local residents in the effective management of e-waste. The questionnaire's content was validated by three experts in the field. The Index of Item Objective Congruence (IOC) was assessed to determine the relevance between the questions asked (Resulting IOC = 0.984). In addition, the refined questionnaire was pretested on a sample of 30 people living in southern Thailand with characteristics similar to those of the research samples (Cronbach's α value = 0.981). Data were collected through questionnaires, entered into Excel 2021, and analyzed via SPSS (IBM Version 25). Descriptive statistics included percentages and frequency values for the variables. Simple linear regression was employed to analyze the effects of average perception, knowledge, and attitude scores on the average behavior score, both univariately and interactively. The results of perception, knowledge, attitudes, and behavior are interpreted into 3 levels, namely, low, moderate and high, as applied in Bloom [25]. In addition, inferential statistics such as the Pearson product moment correlation coefficient and multiple regression analysis were utilized.

3) Collaborative governance among the government, private sector and local residents in e-waste management

Collaborative governance was conducted in one province within the entire southern region. The study focused on three groups of stakeholders: government officers, the private sector, and local residents in Nakhon Si Thammarat Province, which is a pilot province. Eleven government officers are representatives of administrative organization officers, natural resource officers, public health officers, local administration officers, and subdistrict administrative organization officers who work on and are concerned with e-waste management. Thirteen private sector employees are business owners or workers working in e-waste recycling facilities. Thirty-two community members were interested in e-waste management. Collaborative governance was used in SWOT analysis for e-waste management, and data on guidelines for appropriate e-waste management in different contexts were analyzed.

Results and discussion

1) Government concerns in e-waste management

1.1) Recent problems

The management of e-waste poses various problems in southern Thailand. Different types of e-waste are disposed of differently. Small e-waste, such as mobile phones and light bulbs, is often treated as domestic waste or openly dumped. On the other hand, large amounts of e-waste, such as televisions, computer screens, washing machines and refrigerators, are mostly abandoned near garbage bins or openly dumped, leading to toxic contamination, particularly from heavy metals and POPs, in domestic landfills [26–28]. Some electronic equipment is left behind at repair shops when it cannot be fixed, whereas other e-waste is sold to second-hand shops, where it is dismantled. In some cases, electronic wires are burned for copper, disregarding

safety and sanitation concerns. Although this problem is common in developing countries, it is a serious global concern due to health hazards and environmental contamination [13, 29–32]. Coastal communities often resort to dumping large amounts of e-waste into the sea. Furthermore, neighboring countries import second-hand electronic appliances into bordering provinces, which have short service lives and could generate a substantial amount of e-waste in the near future.

1.2) Recent solutions

The local government of 14 provinces in southern Thailand has taken responsibility for four approaches, as illustrated in Figure 1: A) collecting and transporting light bulbs and batteries for disposal; B) collecting and transporting light bulbs, batteries, and certain e-waste, such as computer screens, mobile phones, and televisions for disposal; C) collecting and transporting light bulbs, batteries and all types of e-waste for disposal; and D) collecting light bulbs, batteries, and some e-waste, including computer screens and television but transporting only light bulbs and batteries for disposal. There are 5 provinces (35.72%) for Model (A), 2 provinces (14.28%) for Model (B), 6 provinces (42.85%) for Model (C), and 1 province (7.15%) for Model (D). For approaches (A), (B), and (C), the local government covers the disposal fees for 13 provinces (92.85%), whereas only 1 province (7.15%) in approach (D) individuals is responsible for paying the fee on the basis of the polluters pays principle (PPP) for e-waste disposal. Importantly, there is no obligation for e-waste producers in any of these approaches. Each approach has advantages and disadvantages, and the most effective approach is not clear. In all approaches, light bulbs and batteries that are not worth recycling are collected and transported for disposal. However, there is still a need for proper collection and disposal of other remaining e-waste. Approaches (B) and (C), which involve collecting and transporting certain or all e-waste for disposal, are convenient for local residents but result in loss opportunities for recycling or salvaging workable parts and valuable elements. Additionally, they require a significant investment. In approach (D), large amounts of e-waste are not immediately transported for disposal but are instead stored at the collection site awaiting deportation or recycling.

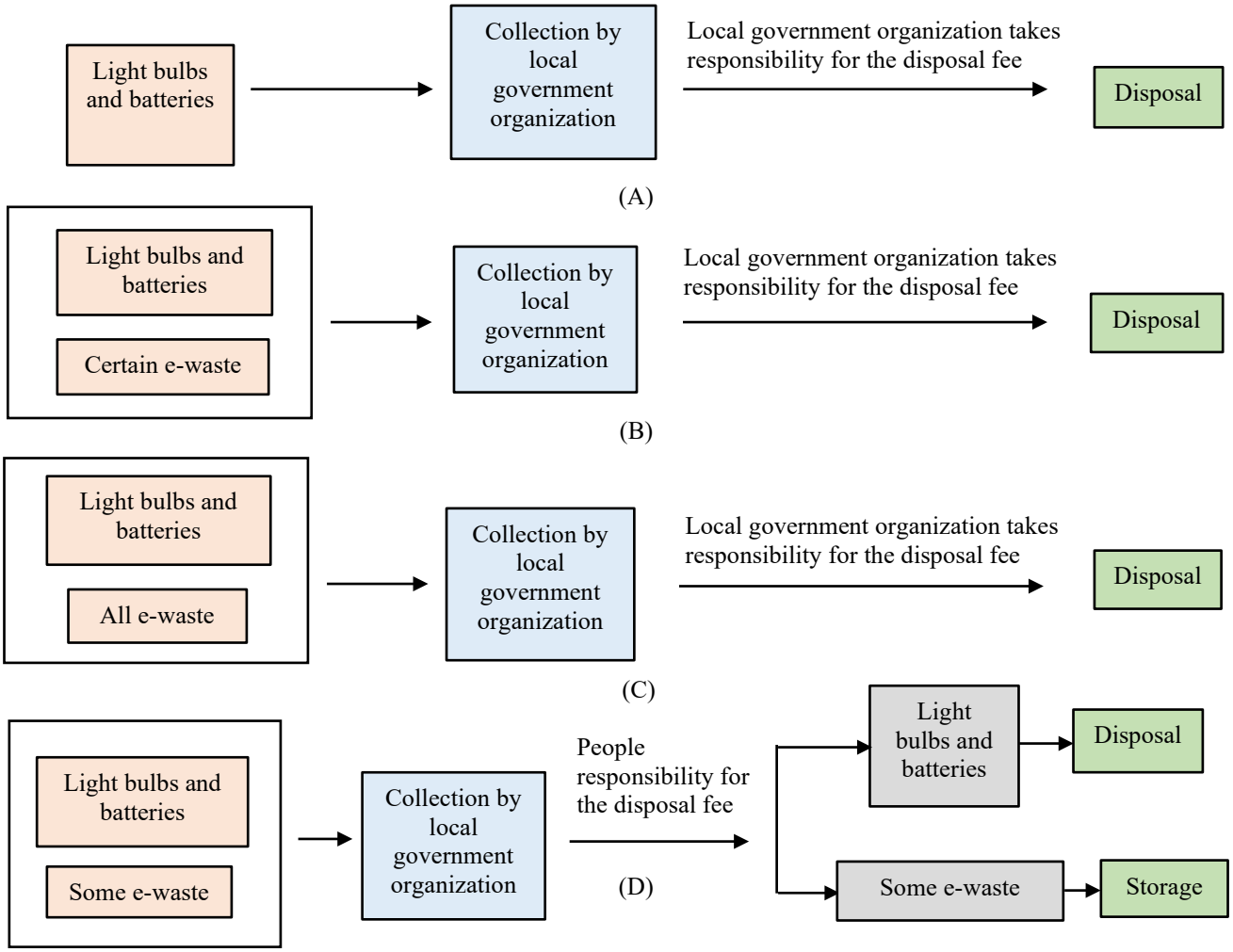

Figure 1 E-waste collection and disposal approaches.

3) Guidelines for problem solving

The solution to the e-waste problem in southern Thailand should start with the government designating e-waste management as a national priority. Clear policies should be established at the central level, which should then be implemented at the local level, or laws specifically addressing the management of e-waste. It is important to initiate a product take-back system for electronic devices and appliances, or e-waste, by seeking cooperation from private sector entities involved in producing, selling, and servicing these products to support their collection. However, a designated organization at the provincial level needs to oversee the collection process, which currently needs improvement. Therefore, this approach still needs to be successfully implemented.

To address the current e-waste problem, local administrative organizations (LAOs) and government agencies should focus on publicizing and educating the public about the dangers and impacts of e-waste on both health and the environment. They should also be aware of proper e-waste management, including safe separation and collection, without disassembling the devices. Cooperation with the private sector is essential, such as organizing mobile phone e-waste management initiatives, with joint efforts from public and private organizations, including campaigns such as “Thailand Without E-Waste” and “Old Phones, New Lives.” These initiatives are good examples of effective mobile phone waste collection and proper disposal. Such activities should be ongoing, and private sector entities could assist by providing collection points for e-waste. Additionally, the government should monitor and prevent illegal imports of e-waste from neighboring countries.

4) Trends regarding future regulations for remedies

In the future, e-waste management should be supported by government regulations that promote mechanisms for handling e-waste in line with the extended producer responsibility (EPR) principle. This approach encourages producers to take full responsibility for the environmental impacts of their products throughout their life cycle. Manufacturers must manage e-waste postconsumption by implementing systems or mechanisms for product take-back and proper disposal. A combined approach involving EPR legislation and an e-waste management fund could be implemented. The fund would cover expenses for supporting and promoting the development of e-waste management systems.

Furthermore, collaboration with the public, from initial waste handling to final disposal, and partnerships with scrap dealers and electronics retailers should be strengthened. For instance, a coupon redemption system could be established to encourage product returns. Recycling businesses should be promoted, and e-waste recycling plants should be built to recover valuable materials, alongside hazardous waste treatment facilities in every region, to ensure convenient access for recycling and disposal. Additionally, laws should control the importation of secondhand electrical appliances and electronic equipment.

In Thailand, concrete regulations and laws regarding e-waste management must be enacted. In 2007, a national strategy for managing WEEE was launched [33]. Recently, the draft WEEE Act has been revised, where stakeholder involvement and the principle of EPR will be included in the amendment. The stakeholders involved should encompass government sections, private sectors, and local residents. The revised regulation should cover the entire e-waste management process, including the return of e-waste products and the collection and transportation of e-waste from all relevant parties, not only households but also secondhand shops and small recycling entities. Proper regulation specifically tailored to e-waste, effective control of e-waste dumping, technology transfer for e-waste recycling, stakeholder participation, and EPR implementation are key to success in e-waste management. Over 78 countries, including 17 in Asia, have enacted specific laws and regulations for e-waste management [4]. The principle of EPR is applied in numerous countries, such as the Netherlands, the United Kingdom, Germany, Switzerland, Belgium, Denmark, Sweden, Portugal, India, Japan, Korea, Taiwan, and Vietnam [34–35]. In developing countries, the implementation of the EPR program has become crucial because of the high level of transboundary movement of e-waste and the lack of basic recycling and waste disposal facilities [36].

To create a truly effective e-waste management system in the future, the government should establish clear guidelines on where and how to dispose of e-waste, who is responsible for managing it, and who is authorized to dismantle or disassemble the products. The role of scrap dealers should be clearly defined, including who is responsible for collection, where collection centers are located, how waste is transported, and how it is recycled or disposed of. The budget for these operations should also be determined. The government could drive effective e-waste management with clear policies and designated responsibilities. Additionally, the government should continuously campaign to increase public awareness and understanding of e-waste management to foster long-term sustainable behaviors.

2) Local residents’ concerns in e-waste management

As presented in Figure 2 and Table 1, the study of the general characteristics affecting e-waste management in southern Thailand revealed statistically significant associations between all factors and knowledge of e-waste management (p value < 0.05). Moreover, age, status, education, career, and income were also found to have significant associations with perceptions,

knowledge and attitudes toward e-waste management (p value <0.05), whereas gender had a statistically significant effect on knowledge and attitudes (p value < 0.05); however, administrative area presented a statistically significant effect on perceptions and knowledge of e-waste management (p value <0.05). Gender significantly influences knowledge and attitudes toward e-waste management, which aligns with the findings of studies by Ekere et al. [37], who reported that gender differences impact household waste utilization and separation behavior, and Talalaj & Walery [38], who reported that the waste generation rate was more dependent on the ratio of men to women than on the quantitative size of each group. The respondents under 20 years of age had significantly different perceptions, knowledge, and attitudes toward e-waste management than did those aged 51-60 years. Manika et al. [39] reported that individuals aged 18-30 years are more likely to generate large amounts of food waste, whereas Shaw [40] reported that retirees exhibit more environmentally friendly waste management behaviors than younger generations do. However, general characteristics were not found to be linked to the behavior of local residents in e-waste management. A comparable outcome was observed in the study by Aboelmaged [41], where the components of the theory of planned behavior (TPB) related to behavioral control did not significantly affect the recycling intentions of young e-waste consumers.

In terms of perception, approximately 50% of the population has been exposed to information and campaigns related to e-waste disposal, whereas the other half has yet to. Additionally, more than 70% of people have never participated in e-waste management campaigns, and many citizens have not received any information on e-waste disposal through media. Only 58.5% of the respondents, or 936 people, had a low level of perception, as shown in Table 1. The low perception may be because the government and local authorities have addressed only e-waste in general waste, grouping it with hazardous waste without targeted campaigns or a clear understanding of e-waste specifically. Furthermore, e-waste management needs a clear framework or legal guidelines. The Electronic Waste Management Act has long awaited enactment.

With respect to knowledge about e-waste disposal and management, 67.4% of the respondents, or 1,079 people, had a high level of knowledge, as indicated in Table 1. However, many people still need to understand that they should store e-waste until it accumulates and then separate valuable components themselves, with 57.3% of respondents, or 916 people, having this misconception. Moreover, 67.2% of the respondents, or 1,075 people, believe that e-waste can be disposed of by burying or burning, indicating a need for increased awareness of the potential for environmental contamination and health risks from toxic substances. Improper e-waste disposal can lead to pollutants contaminating air, soil, and water, directly or indirectly impacting humans and the environment [29].

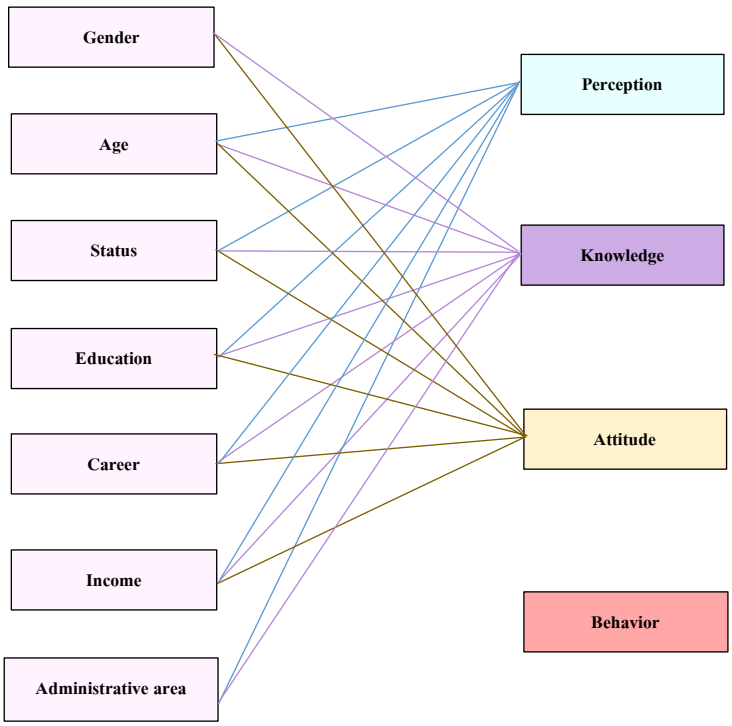

Figure 2 Relationships between general characteristics and the perceptions of news, relevant knowledge, attitudes, and behaviors related to e-waste management.

Table 1 General characteristics affecting e-waste management

Items	N (1600)	Perception				Knowledge				Attitude				Behavior			
		Low (936) 58.5%	Moderate (277) 17.3%	High (387) 24.2%	p value	Low (91) 5.7%	Moderate (430) 26.9%	High (1,079) 67.4%	p value	Low (2) 0.1%	Moderate (598) 26.9%	High (1,000) 62.5%	p value	Low (29) 1.8%	Moderate (1,433) 89.6%	High (138) 8.6%	p value
Gender					0.392				0.000*				0.000*				0.686
Male	677	404	107	166		57	206	414		0	308	369		10	609	58	
Female	923	532	170	221		34	224	665		2	290	631		19	824	80	
Age					0.000*				0.000*				0.000*				0.798
≤ 20 year	136	49	38	49		20	60	56		1	89	46		1	121	14	
21-30 year	776	455	148	173		59	263	454		0	361	415		14	703	59	
31-40 year	302	192	40	70		8	65	229		0	83	219		7	266	29	
41-50 year	274	178	41	55		4	27	243		0	50	224		6	241	27	
51-60 year	96	49	9	38		0	13	83		1	12	83		1	86	9	
≥ 61 year	16	13	1	2		0	2	14		0	3	13		0	16	0	
Status					0.021*				0.000*				0.000*				0.732
Single	1,023	576	198	249		76	312	635		1	443	579		15	923	85	
Married	521	319	72	130		14	104	403		0	143	378		12	460	49	
Widow	21	13	3	5		0	5	16		1	5	15		1	19	1	
Divorced	35	28	4	3		1	9	25		0	7	28		1	31	3	
Education					0.000*				0.000*				0.000*				0.894
Primary school	57	39	8	10		9	31	17		0	37	20		1	50	6	
Secondary school/Vocational certificate	424	218	90	116		41	172	211		1	250	173		7	387	30	
Undergraduate	878	505	152	221		39	206	633		1	289	588		16	782	80	
Graduate	241	174	27	40		2	21	218		0	22	219		5	214	22	
Career					0.001*				0.000*				0.000*				0.058
Farmer/Fisherman	79	54	6	19		6	11	62		1	28	50		1	70	8	
Business	144	94	20	30		13	26	105		0	60	84		3	126	15	
Government official/State enterprise employee	613	365	98	150		26	143	444		0	174	439		9	545	59	
Employee	285	179	46	60		5	83	197		0	96	189		6	261	18	
Housewife/House husbands	27	16	3	8		2	8	17		0	12	15		3	23	1	
Student	452	228	104	120		39	159	254		1	228	223		7	408	37	

Table 1 General characteristics affecting e-waste management (*continued*)

Items	N (1600)	Perception				Knowledge				Attitude				Behavior			
		Low (936) 58.5%	**Moderate (277) 17.3%**	**High (387) 24.2%**	**p value**	**Low (91) 5.7%**	**Moderate (430) 26.9%**	**High (1,079) 67.4%**	**p value**	**Low (2) 0.1%**	**Moderate (598) 26.9%**	**High (1,000) 62.5%**	**p value**	**Low (29) 1.8%**	**Moderate (1,433) 89.6%**	**High (138) 8.6%**	**p value**
Income					0.005*				0.000*				0.000*				0.800
≤ 10,000 THB	690	383	141	166		65	250	375		2	353	335		10	624	56	
10,001-20,000 THB	421	241	71	109		20	119	282		0	159	262		8	372	41	
20,001-30,000 THB	168	104	23	41		4	25	139		0	42	126		4	146	18	
30,001-40,000 THB	152	86	23	43		0	18	134		0	27	125		2	138	12	
40,001-50,000 THB	73	47	10	16		0	9	64		0	10	63		2	68	3	
≥ 50,000 THB	96	75	9	12		2	9	85		0	7	89		3	85	8	
Administrative area					0.000*				0.009*				0.249				0.904
City municipality	150	78	32	40		3	32	115		0	46	104		2	137	11	
Town Municipality	408	207	79	122		28	98	282		0	150	258		5	369	34	
Subdistrict Municipality	448	276	83	89		30	142	276		0	180	268		10	397	41	
Subdistrict administrative organization	594	375	83	136		30	158	406		2	222	370		12	530	52	

Remark: * Significant at p value ≤ 0.05

For attitudes toward e-waste disposal and management, 62.5% of the respondents, or 1,000 people, had a high level of attitudes, as indicated in Table 1. In addition, 57.2% of the respondents, or 915 people, believed that the government should play a significant role in managing e-waste. On the other hand, 75.1% of the respondents, or 1,201 people, disagreed that e-waste should be mixed with general waste. Another 56.9%, or 910 people, were against storing e-waste at home. The public generally has a favorable attitude toward responsible behaviors, as 56.6% of the respondents, or 905 people, reported that they had never buried or burned e-waste, and 45.1%, or 721 people, said that they had not separated valuable components on their own. The majority of the respondents, 89.6%, or 1,433 people, displayed moderate behavior, as shown in Table 1. Improper behaviors can lead to toxic contamination of the environment.

With respect to the relationships between behaviors related to e-waste management and the perception of news, relevant knowledge, and attitudes (Table 2), strong relationships between actions related to e-waste management and the perception of news and attitudes were found. Knowledge was not statistically related to actions related to e-waste management. The results of simple linear regression analysis revealed that perceptions (B = 0.065, t = 6.657, p value = 0.000) and attitudes (B = 0.079, t = 4.350, p value = 0.000) significantly influenced behaviors related to e-waste disposal and management at the .01 level. Moreover, knowledge did not have a significant relationship with these behaviors. This finding is consistent with the study by Almasi et al. [42], which revealed that while 79% and 86% of the public had good knowledge and attitudes, respectively, only 77% exhibited low action levels in managing solid waste according to the 3rd principle. Similarly, Limon et al. [43] reported that although the public had good knowledge of mask disposal, their behavior needed to be corrected.

Table 2 Relationships between behaviors in e-waste management and perceptions of news, relevant knowledge, and attitudes

Factors	B	t	95% CI for B	p value
Perception	0.065	6.657	0.046-0.083	0.000*
Knowledge	0.016	1.063	-0.13-0.045	0.288
Attitude	0.079	4.350	0.43-0.115	0.000*

Remark: *statistically significant at 0.01

Local actions for managing broken/disused electronic appliances, as briefed in Table 3, show that repairing appliances is the most common action (44.5%). Common appliances to be repaired include large electronic equipment (refrigerators, air conditioners, and washing machines), small equipment (microwave and fans), information technology equipment (computers, printers and fax) and entertainment equipment (televisions and radios). Some people kept their appliances home (29.6%), while some sold them to secondhand shops (14.9%). Mobile phones, telephones, cameras, and video (VDO) recorders are typically kept at home. Very few people disposed of them with either domestic waste (2%) or hazardous waste (1%). In contrast, at the national level, the Pollution Control Department [23] reported that most Thai people sold broken/disused electronic appliances (51.3%). Some people kept their appliances at home (25.3%), some disposed of them with domestic waste (15.6%), and some donated them to others (7.8%). Compared with other countries, 7–20% of people in high-income countries export e-waste as second-hand products, and 8% of those binned them in a regular trash can [4]. In contrast, most American people handed broken televisions to be recycled. Some kept them at home, reused them, and binned them [44]. In Macau, 25.09% of people sell e-waste binned, 19.06% return it to sellers, 12.99% keep it at home, and 11.25% donate [16]. In India, some e-waste can be traded with new electronic appliances; 32% of Indian people take that option, whereas 18% keep the waste at home [45]. For Brazilians, 36% keep e-waste at home, 24% binned, 23% donated, and 8% sold it away [46]. Moreover, establishing a product take-back system for electronic devices or e-waste is essential. The government can achieve this by encouraging collaboration with private sector companies that produce, sell, and service these products to assist with their collection.

Concerning the service life of electronic appliances, as shown in Table 4, the electronic appliances used in 2022 seem to have a longer lifespan than they did a decade ago [23] but much shorter lifespan than they did in 2003 [47]. This could be caused by a better awareness of environmental conservation and hazards from e-waste. In addition, COVID-19, which has caused a worldwide economic crisis, could make people more frugal. Compared with that in other countries (Table 4), the lifespan of electronic appliances in Thailand is longer than that in Vietnam but shorter than that in China and Western Europe [48–51]. Nevertheless, despite customers' concerns about using and taking care of electronic appliances, the quality of products from producers is another crucial factor in this issue.

Table 3 Actions for managing broken/disused electronic appliances

Actions/ Electronic appliances	Keeping at home (%)	Repairing (%)	Donation (%)	Selling to secondhand shop (%)	Disposing with domestic waste (%)	Disposing with hazardous waste (%)
Refrigerators	24.7	48.1	8.6	17.4	0.7	0.5
Air conditioners	20.9	50.9	7.5	18.5	1.4	0.8
Washing machines	20.0	53.3	7.7	17.6	0.7	0.7
Microwave	28.4	40.5	9.4	18.3	1.8	1.6
Fans	22.6	52.4	5.9	15.6	2.9	0.6
Mobile phones	43.9	34.7	6.7	8.8	2.5	3.4
Telephones	41.0	31.4	8.3	12.2	4.3	2.6
Desktop computers	34.0	44.4	7.4	11.0	1.0	2.2
Notebook computers	33.3	47.2	7.0	10.0	0.9	1.5
Printers	33.2	42.0	8.0	13.7	1.3	1.8
Fax	31.8	38.9	9.6	15.2	2.7	1.9
Televisions	28.6	47.8	7.6	13.8	0.9	1.2
Radios	35.5	36.7	8.1	15.2	2.8	1.7
Cameras/VDO recorders	40.4	38.8	6.6	10.1	2.3	1.8
Total	29.6	44.5	7.7	14.9	1.9	1.4

Table 4 Comparison of the lifespans of electronic appliances

Electronic appliance	Average lifespan (year)							
	Thailand			China		Vietnam		Western Europe
	2022 This study	2012 [31]	2003 [36]	2020 [37]	2008 [38]	2013 [39]	2006 [39]	2008 [40]
Refrigerators	9.2	6.87	14	11-19	10-16	4.7	7.5	10
Air conditioners	7.8	5.20	10	11-19	10-16	4.7	10.5	10
Washing machines	7.9	-	12	11-19	10-16	4.6	6.5	8
Microwave	5.8	-	-	-	-	-	-	7
Fans	4.4	3.09	-	-	-	-	-	-
Mobile phones	6.9	6.31	-	-	-	-	-	5
Telephones	6.3	3.65	7	11-17	4-6	-	-	4
Desktop computers	5.9	3.65	7	-	-	-	-	-
Televisions	7.6	3.80	-	11-19	8-12	7.6	7.7	10
Radios	6.0	-	-	-	-	-	-	10

3) Government, private sector and local residents' concerns in e-waste management

According to a workshop on a pilot province, the strengths of recent procedures for managing e-waste include the following: (1) the main section took responsibility for collecting, transporting and disposing of e-waste and paying all fees; and (2) many secondhand shops were found in the area. In contrast, the weaknesses involved (1) unclear procedures for managing e-waste; (2) no participation from every section in e-waste management; (3) no constant campaign for building the proper understanding and knowledge regarding the issue; (4) a lack of appropriate collection sites; and (5) inappropriate sanitary management procedures for most recycling shops and no health risk monitoring. Threat found in the area was likely common. There was no separation of any waste, particularly e-waste, from domestic waste. Nevertheless, many studies have revealed that (1) the draft WEEE was revised; (2) strong groups of local residents, such as environmental and public health volunteers, could effectively promote the right understanding and knowledge of e-waste management; and (3) the heads of local residents and local governments were closed to the communities, leading to increased effectiveness of any work in the area.

4) Limitations of the study

This study collected data during the COVID-19 pandemic in Thailand via both face-to-face interviews and online sampling. The sample was randomly selected, and the distribution of questionnaires in each province was proportional to the population ratio. However, sex and age group distributions were not considered in the proportional selection.

Conclusion

The e-waste problem in southern Thailand has reached distressing levels. E-waste is often disposed of alongside regular domestic waste, left at repair shops, discarded in garbage bins, or even openly dumped. Some e-waste is sold to second-hand shops, where certain components are separated.

The government has taken responsibility for four approaches: (A) collecting and transporting light bulbs and batteries for disposal; (B) collecting and transporting light bulbs, batteries and some large e-waste items for disposal; (C) collecting and transporting light bulbs, batteries and all types of e-waste for disposal; and (D) collecting light bulbs, batteries, and some e-waste and transporting only light bulbs and batteries for disposal. For approaches (A), (B), and (C), the local government covers the disposal fee, whereas in approach (D), individuals are responsible for the fee. However, a revision of the draft WEEE Act is underway, which will include stakeholder involvement and the principle of EPR.

Local residents display limited awareness of e-waste management, yet they appear to possess substantial knowledge and positive attitudes toward the issue. The majority of residents believe that the government should be responsible for managing e-waste. Statistically significant relationships were identified between e-waste management behaviors, news perceptions, and attitudes. Repairing appliances is the most common action taken (44.5%). The appliances that are commonly repaired include large electronic equipment (such as refrigerators, air conditioners and washing machines), small devices (microwave and fans), information technology equipment (computers, printers and fax machines), and entertainment devices (televisions and radios). Currently, electronic appliances have longer service lives than they did a decade ago.

With respect to concerns expressed by the government, private sector and local residents about e-waste management, strengths were observed in the clear allocation of responsibilities and the presence of secondhand shops. Weaknesses included unclear e-waste management procedures, insufficient participation in management efforts, a lack of consistent education campaigns, inadequate collection sites, and inappropriate sanitary management procedures in most recycling shops. A prevalent issue was the failure to segregate waste, especially e-waste, from regular domestic waste. Nonetheless, numerous opportunities were identified, including the revision of the draft WEEE Act and the presence of strong local residents with influential leaders who can effectively promote understanding and knowledge about e-waste management.

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