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Demonstrating the effects of behavioral control beliefs on the actual WEEE discharge routes: A case study in South Korea

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ABSTRACT

Since 2008, South Korea has operated the Extended Producer Responsibility (EPR) system, which collects and recycles waste electrical and electronic equipment (WEEE). Although the EPR recycled 305,050 tons of WEEE in 2017, approximately 62.5% remained in the informal sector, posing potential risks to the environment. This study is intended to provide information on consumer behavior regarding the discharge of WEEE and to analyze the causality between consumer beliefs and behavior, using the theory of planned behavior (TPB) model to establish strategies for maximizing the flow of WEEE through the formal sector. In accordance with the methodology, questionnaire data were collected from 2,000 respondents, who were selected through a stratified procedure, using computer-assisted telephone interviews to investigate their behavior related to the discharge of WEEE. According to the results, about 31.50% of the respondents had disposed of WEEE in 2017, and the most frequently discarded item was a refrigerator (35.08%). *Local authorities* (38.95%) and *take back* (37.30%) were the preferred means of discarding large- and mid-sized appliances. According to the TPB analysis, norm and control beliefs for discarding WEEE through the formal sector significantly affected behavioral intention ($p \leq 0.001$). Furthermore, controlbeliefs directly affected actual discharge behavior ($B = 1.351$, $p \leq 0.001$)and actual discharge routes ($B = 0.846$, $p \leq 0.05$). These results indicate that the TPB can provide political strategies for discarding WEEE through the formal sector based on the causality between consumer beliefs and actual consumer behavior.

1. Introduction

The quantity of waste electrical and electronic equipment (WEEE), particularly in the form of end-of-life electrical and electronic appliances discarded by consumers, is dramatically increasing worldwide. Previous studies estimate that 8.9 million tons of WEEE, which is approximately 20% of all waste generation (44.7 million tons), was collected and recycled worldwide in 2016 (Balde et al., 2017; Mihai et al., 2019). A similar trend exists in South Korea.

In 2012, 138 thousand tons of e-waste were recycled through the formal sector in South Korea. This increased to 155 thousand tons in 2013 (12.31% increase compared to the previous year), 181 thousand tons in 2014 (16.77%), 199 thousand tons in 2015 (9.94%), 249 thousand tons in 2016 (25.12%), 271 thousand tons in 2017 (8.83%), 305 thousand tons in 2018 (12.54%), and 319 thousand tons in 2019 (4.59%) (Park et al., 2019a; Park et al., 2019b; Korea Electronics Recycling Cooperative, 2019). This growth indicated an increase approximately 131.16% from 2012 to 2019. Many global reports and studies have estimated that approximately 665 thousand tonsof e-waste were generated in South Korean in 2016, but the actual recycling achievement in the formal sector was 249 thousand tons, implying that the remaining 416 thousand tons of e-waste likely leaked into the informal sector (Yang et al., 2015; Balde et al., 2017).

With an increase in the amount of WEEE and its leakage into the informal sector, concern has risen over the adverse effect this could have on human health and the environment. Often illegally neglected or abandoned e-waste ends up in landfills or incineration plants without pre-treatment processes, such as the recovery of toxic materials or refrigerants (Buekens and Yang, 2014; Gu et al., 2016; Park et al., 2019a). Toxic materials, such as brominated flame retardants, heavy metals, and persistent organic pollutants, and their associated risks have been reported in numerous previous studies (Chan and Xing, 2007; Babayemi et al., 2015; Zhuang, 2019; Oi and Leung, 2019). In South Korea, the Eco-Assurance System (Eco-AS) was established in 2008 to

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manage harmful and toxic materials properly and to construct a recycling system with administrative regulation in the formal sector (KEC, 2019a; Park et al., 2018,2019a, 2019b). The goal of the Eco-AS is to minimize the environmental load through the systematic management of the entire life cycle of WEEE. It supervises the illegal management of harmful materials, such as fluorescent material (cathode-ray tube televisions, or CRT TVs), refrigerants (refrigerators, water purifiers, and air conditioners), cartridges (printers and copiers), and cold-cathode fluorescent lamps (LCD TVs) (KLRI, 2019a, 2019b; Park et al., 2020). Since 2014, the Eco-AS has identified 27 WEEE items as target items in four different categories: large-size, mid-size, small-size, and telecommunications (Table S1).

The Eco-AS is also able to quantify the collection, transport, and recycling performance of all types of e-waste in the formal sector of South Korea statistically (APEC-VC-Korea, 2019; KEC, 2019b). In contrast, difficulty quantifying the handling of e-waste statistically is a weakness of the informal sector (in addition to the environmental and human health problems associated with the illegal discharge of e-waste). Specifically, disposal operators in the informal sector do not gather "collection quantity" statistics for the e-waste they collected or purchase; they only compile some statistics for the final "resources and/or waste quantity" of each material after final disposal, and even that is not mandatory (Manomavool and Ho, 2014; Park et al., 2019a).

Despite the publication of many papers on WEEE-related topics in South Korea, such as government policies, operational systems, recycling technologies and their statuses, only a few studies have been done on consumer behavior with regard to the discharge of WEEE. Jang and Kim (2010) studied the generation rate, collection system, and method of systematic recycling using survey responses from 1,090 consumers in South Korea regarding mobile phone handset recycling status. Similarly, although not intended for consumers, Kim et al. (2013) conducted a study that surveyed waste management experts to determine a list of regulatory priorities in the WEEE recycling process, using the Delphi method and analytical hierarchy process modeling as a policy-making tool. The questionnaire survey-response method has been used in a few studies to estimate the total annual quantity of WEEE generation (Jang, 2010; Kim et al., 2013; Manomavool and Ho, 2014; Guo et al., 2018). Thus, consumer behavior, including actual discharge frequency, route, and product information, toward WEEE has been insufficiently analyzed both quantitatively and qualitatively in the research, although the available research can be valuable for governmental policy-making and system management.

Unlike South Korea, countries like China, the United States, and those in the European Union have been increasing research in this area. Some of these studies have analyzed consumer behavior related to WEEE discharge based on the theory of planned behavior (TPB), mainly using case studies. The basic concept of the TPB is that three considerations guide human behavior (Ajzen, 1991): *behavioral beliefs*, which are beliefs about the likely consequences or other characteristics of behavior (e.g., normative motivation and behavioral intention); *normative beliefs*, which are beliefs about the normative expectations of other people; and *control beliefs*, which are beliefs about the presence of factors that may further or impede the performance of a behavior. Thus, behavioral beliefs produce a favorable or unfavorable attitude toward a behavior, normative beliefs lead to perceived social pressure or a subjective norm, and control beliefs lead to perceived behavioral control and the ease or difficulty of a perceived behavior (Ajzen, 2002).

In several countries, studies using the TPB have expressed support for the establishment of WEEE management strategies that consider consumer behavior (Parajuly et al., 2020). Echegaray and Valeria (2016) conducted an analysis of consumer intentions and behavior with respect to the sociodemographic and economic factors for e-waste recycling and disposal using a TPB-based questionnaire survey in a metropolitan area of Brazil. Their results indicated that the majority of respondents, namely low-income women, middle-aged individuals, and residents in the southeastern region, had positive intentions for recycling e-waste; in contrast, a few high-income respondents were found to place a greater emphasis on disposal, such as in a landfill or via incineration, without recycling. Haron et al. (2018) used the TPB to analyze factors affecting WEEE recycling participation in Sudan and found that confidence in recycling methods, belief in environmental degradation, recycling convenience, and social pressure were influential factors on recycling behavior. Similarly, Wang et al. (2016) analyzed factors influencing residents' perception of informal recycling on their intention to recycle WEEE. The main influencing factors were environmental awareness, attitude toward recycling, perception of informal recycling, cost of recycling, and income. The factors that indirectly influenced citizens' intention to act through awareness of informal recycling were norms and publicity. Among these factors, awareness, and attitude were rated as the most influential factors. Le et al., 2013 also investigate the determinants of WEEE recycling behavior with the aim of designing a management and recycling system for WEEE in Vietnam. They found that the most important predictor was perceived behavior control, the second strongest predictor was subjective norm, and the weakest predictor was attitude. Kumar (2019) analyzed the main influence factors affecting the e-waste recycling behavior of Chinese and Indian young adults from different cultures. Perceived control and subjective norm were found to be the stronger factors related to the Chinese young adults' intention to recycle WEEE than the Indian participants' intention. In comparison, attitude and individual responsibility were found to be stronger factors among the Indian participants than the Chinese participants. Using the structural equation model and TPB, Botetzagias et al. (2015) analyzed how moral norms and demographic features affect the behavioral intention to recycle household waste. Their results revealed that perceived behavioral control was consistently the most important explainable variable, and the moral norm had a greater effect on behavioral intentions than attitudes.

The aim of this study was to investigate and analyze consumer behavior related to WEEE discharge in South Korea, to diagnose potential problems that may occur in the WEEE disposal process, and to offer solutions to these problems. Using the TPB model, the responses to a questionnaire on consumer behavior and behavioral, norm, and control beliefs were analyzed to identify the factors related to consumer decision-making in the discharge of e-waste in South Korea. By analyzing the survey data, we then developed suggestions for improving South Korea's WEEE collection and recycling system in future strategic planning.

The present study differs from previous research in three significant ways. First, the questionnaire survey was designed using a professional telephone questionnaire method (2,000 respondents) to analyze the respondents' discharge features, such as the WEEE products and routes discharged, based on their actual experience. It is the first research conducted on the e-waste topic in South Korea. Second, based on the actual industrial field of e-waste disposition in South Korea and the discharge routes, such as formal and informal sectors, an in-depth analysis of the discharge routes according to social (age, region, and gender) and product characteristics (large, mid, and small-size) was implemented to develop a strategy: to expand the formal sector, inducing the discharge of more e-waste through the formal sector. Finally, by establishing the attitude, subjective norm, and perceived behavioral control variables of respondents with experience in the actual discharge of e-waste, the present study explains the intention of discharging e-waste through the formal sector and the interaction between the actual discharge path and action. Ultimately, using the TPB, we examined how three predictable key variables (attitude, subjective norm, and perceived behavior control) can affect consumers' discharge intention of e-waste through the formal sector and the actual discharge route.

2. Discharge routes in South Korea

WEEE discharge routes can be divided into four categories, with some sub-routes that depend on whether the consumer pays a fee. The specific routes are *local authorities, take back, door-to-door (d-to-d)* free pickup system, and *personal recyclers*. Among these four routes, *take back* and *d-to-d* are fully categorized as belonging to the formal sector, managing large quantities of WEEE legally through the Ministry of Environment (MOE) of the Korean government. However, *local authorities* and *personal recyclers* are considered to be informal sector routes because it is difficult to classify as belonging to the formal.

(1) *Local authorities*: This route is an important WEEE collection route in South Korea because it is highly accessible to the general public in their daily routine. In this system, the consumer pays a fee to the local government and receive stickers to attach to the end-of-life household appliances, which consumers then placed outside their homes. Despite the importance of this route, it is estimated that most of the volume of WEEE collected by this means is not treated and recycled through the formal sector. In many cases, consignment companies that have signed a collection and disposal contract with a local government does not have a license or permission to treat the WEEE. Local authorities under the legal scheme managed by the MOE and the Korea Electronics Recycling Cooperative (KERC, as a Producers Responsibility Organization) make up only about 5% of the total quantity of WEEE collected in the formal sector (Park et al., 2019a).
(2) *Take back*: This is a type of reverse logistics in the cycle of electrical and electronic equipment (EEE) sales and WEEE collection. The manufacturer (or importer) and seller of EEE products directly collect old appliances when an EEE engineer visits a consumer's home to install a new product. Through this route, the collecting and recycling processes are fully contained in the formal sector managed by the MOE and KERC (PRO), with annual performance accounting for about 65% of the total quantity of WEEE collected in the formal sector.
(3) *D-to-D service*: This is a collection route that is free of charge so that all Koreans can legally dispose of WEEE in any region in which the MOE collects it. The main effect is the elimination of the opportunity the WEEE collected moves to unlicensed recycling businesses in the informal sector. The real operating agency of the *d-to-d* route is KERC, which manages the funds that are raised from producers, importers, and sellers under the EPR. The collection performance of the *d-to-d* route accounts for about 25% of the total quantity of WEEE collected in the formal sector (Park et al., 2019a,2019b)
(4) *Personal recyclers*: This final route includes all types of collecting paths not mentioned above, which are mostly found in the informal sector. If legal certification is obtained, and the recycler joins KEC or KERC, they become a part of the formal sector. Legal certification implies that the proper machinery can be set up and operated for environmentally friendly recycling processes. Conversely, if the personal recycler is not certified by the MOE, the recycling activity is not included in the national recycling achievement.

3. Methodology

3.1. Study area

The survey area included all cities and provinces of the Republic of Korea. This study divided South Korea into 16 administrative districts (metro-cities and provinces), and the adjacent administrative areas were reclassified into six groups for interpretative and conclusive purposes. The survey, which considered the six main collection routes of WEEE, investigated the actual discharge of end-of-life appliances over the year preceding the survey (2017) and included all responses (e.g., “no experience” or “can't remember”). As of December 2017, when the survey was conducted, all South Koreans had access to all four of the above collection routes regardless of city or province, and there was no known regional discrimination in the collection services.

3.2. Survey design

Computer-assisted telephone interviewing (CATI) is a technique for improving data quality by collecting and editing a respondent's information quickly. It enables interviewers to interact with respondents in a timely manner on the subjects being investigated (Ketola and Klockars, 1999; Kissinger et al., 1999; Choi, 2004). Although the CATI method has fewer time or space limitations than the face-to-face method and is widely used due to its advantage of allowing for stratified sampling, it still introduces a risk of social desirability bias into the survey process. This arises from two points: the sampling step and the interaction between the interviewer and respondent (Groves, R. M., &Mathiowetz, N. A. 1984; Lamanna et al., 2019; Greenleaf et al., 2020). The social desirability bias was minimized in two ways: First, stratified sampling was used to collect respondents. Second, the interaction bias between interviewer and respondents was reduced by hiring experienced CATI experts to conduct the interviews. In addition, it was assumed that there was no social bias caused by economic inequality in the possession of mobile phones, as South Korea has a 100% mobile phone ownership rate and a 95% or higher smartphone penetration rate (Silver and Cornibert, 2019).

In this study, data collection was conducted through a stratified sampling method and was designed to reflect socioeconomic characteristics: gender, age, and region. In the case of gender, the sample was designed to reflect the balance of gender ratios between males and females in the population. The respondents’ ages were classified into 10-year cohorts (30s, 40s, 50s, and 60s); those over 70 years were classified as one cohort, as were those between 15 and 29 years.

The 16 administrative districts were arbitrarily classified into six groups based on the principle of integrating adjacent areas. The survey sampling for each region was based on demographics, and the number of samples in large cities was set at 200 and in small cities at 100, respectively. In other word, the number of samples in all regions was adjusted from 100 to 200 based on the city-size with their population, but since Kyunggi-do is a densely populated area, the highest number of samples was allocated to 220 people (Table 1).

3.2.1. Empirical questionnaire

This study's design, based on stratified sampling techniques and CATI survey methods and considering socioeconomic characteristics, included the following three survey sections (Table S2). First, respondents were asked to indicate whether they had disposed of any e-waste in the previous year (2017) and, if so, what specific types of electronic products were discarded. The second section asked the respondents about their preferred WEEE discharge route. The respondents who had disposed of WEEE within the previous year were asked what route they had taken for the discharge. The responses to the second section on WEEE discharge routes were analyzed using statistical cross-tabulation based on the socioeconomic characteristics of the respondents. The questionnaire data and the answers from the respondents were classified and analyzed according to the CATI survey method, and additional data analysis was performed using IBM SPSS (Version 20). The third section of the survey asked the respondents to answer five sub-questions (three beliefs, behavioral intention, and actual behavior) to provide data for behavioral analysis using the TPB model.

3.2.2. discharge experiences and routes

The first part of the questionnaire asked whether respondents had any actual experience discarding electronic waste in the year prior to the survey (2017). All respondents who had WEEE discharge experience were asked what type of item they had discarded. The second part of

Table 1.
Demographic data of respondents.

	Categories	No. of Respondents (n = 2,000)	Percentage (%)
Gender			
	Male	986	49.30
	Female	1,014	50.70
Age			
	15–29	178	8.90
	30–39	342	17.10
	40–49	454	22.70
	50–59	446	22.30
	60–69	337	16.85
	> 70	243	12.15
Geographical Regions[a]			
Kyunggi-do (Province)	Group 1	220	11.00
Seoul-si (City)	Group 1	200	10.00
Incheon-si (City)	Group 1	120	6.00
Pusan-si	Group 2	130	6.50
Gyeongsangnam-do	Group 2	125	6.25
Gyeongsangbuk-do	Group 2	120	6.00
Daegu-si	Group 2	120	6.00
Ulsan-si	Group 2	100	5.00
Chungcheongnam-do	Group 3	115	5.75
Chungcheongbuk-do	Group 3	110	5.50
Daejeon-si	Group 3	105	5.25
Jeollabuk-do	Group 4	110	5.50
Jeollanam-do	Group 4	110	5.50
Gwangju-si	Group 4	105	5.25
Gangwon-do	Group 5	110	5.50
Jeju-do	Group 6	100	5.00

[a] Cities and provinces were categorized as Group 1 to 6 based on the administrative districts of Korea.

the questionnaire was divided into two subparts: one for all respondents and one for respondents who had WEEE discharge experience. All respondents were asked to indicate their preferred discharge route for discarding e-waste, while respondents with actual e-waste discharge experience were required to list the routes, they used in their previous WEEE discharge experience. Six types of WEEE discharge routes were provided for respondents to choose from: *local authorities(free), local authorities (charges),take back, d-to-d service,personal recyclers, and transfer to others*. In the overall preference survey, the '*others*' mean '*never thought*' and '*can't remember*', but in the actual route survey of respondents who haddischarge experience, the '*others*' indicated the two optional answers that '*no experience*' and '*can't remember*' (Table S2).

Using the methodology described above, we compared and analyzed not only the differences between preferred and actual discharge routes but also the actual discharge route for each WEEE category (large, small, and mid-size appliances), as reported by respondents with actual discharge experience. Finally, the differences in response for WEEE discharge routes and for preferred or actual experience were analyzed based on the socioeconomic characteristics of respondents using a cross-tabulation analysis to verify that they were statistically significant.

3.2.3. The TPB model

To analyze decisive factors and significant effects among attitudes, subjective norms, perceived behavioral control, and behavioral intention using the TPB model, questionnaire surveys were designed using a Likert scale (3- or 5-point). The behavioral belief (attitude) phrase was, "WEEEs need to be discarded through the formal sector." The normative belief (subjective norm) phrase was, "Government and society should encourage the discharging of WEEE through the formal sector." The control belief (perceived behavioral control) phrase was, "It is not difficult to discard WEEE through the formal sector" in compliance with legal regulation. Finally, the intention of behavior (behavioral intention) phrase was, "I am strongly willing to use the formal sector to dispose of WEEE" (Fig. 1). The answers to the above phrases were defined on a 5-point scale as follows: 1 = *Fully disagree*; 2 = *Disagree*; 3 = *Neutral*; 4 = *Agree*; and 5 = *Fully agree*. The answers on a 3-point scale were 1 = *Disagree*; 2 = *Neutral*; and 3 = *Agree*.

A binary variable was used in the first part of the questionnaire: the first question was designed to denote "1" as a respondent with actual discharge experience within the last year and "2" as a respondent without discharge experience within the last year (i.e., during 2017). The second question of the first section was designed to denote "1" as a respondent who had experience discarding WEEE through the informal sector and "2" as a respondent who had experience discarding WEEE through the formal sector.

In the analysis stage, regression analysis was used to determine which belief factors affected behavioral intention. Then, logistic regression analysis was conducted to identify not only if there was a

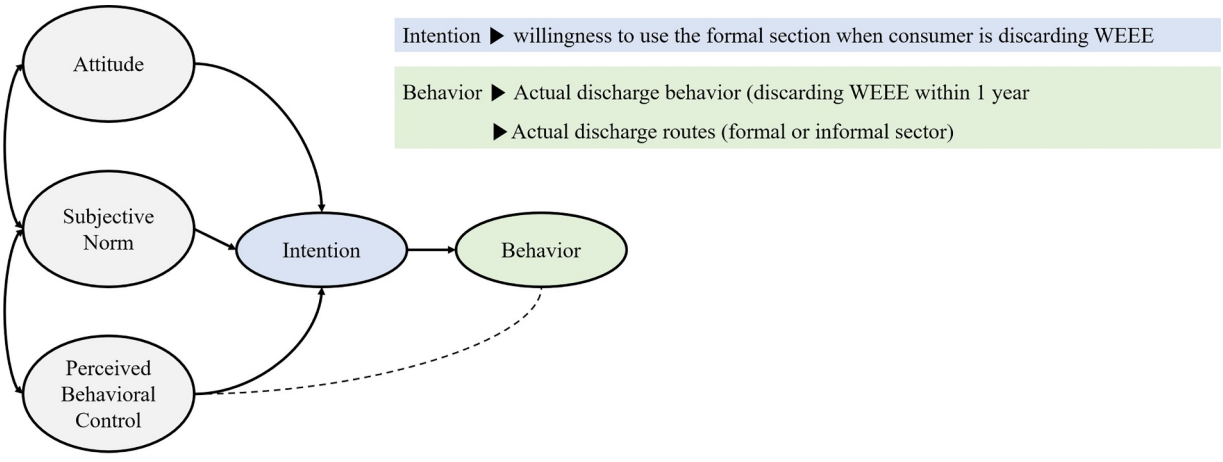

Fig. 1. Schematic diagram of the TPB model using three beliefs (attitude, subjective norm, and perceived behavioral control), behavioral intention, and actual behavior (discharge and routes).

significant effect between control belief and actual discharge behavior but also how the control belief significantly affected the actual discharge route (formal or informal sector) of the respondents who had discharge experience in 2017.

4. Results

4.1. Geographic and demographic characteristics

The geographical characteristics and composition of the participants are shown in Table 1. The respondents were chosen from across South Korea, with each area having 100–220 respondents based on its population. The survey included 16 specific cities (or provinces) categorized into six regions: Region 1 (Seoul-si, Incheon-si, and Kyunggi-do) comprised nearly 27% (n = 540) of the total respondents; Region 2 (Pusan-si, Daegu-si, Ulsan-si, Gyeongsangbuk-do, and Gyeongsangnam-do) comprised 28.76% (n = 595); Region 3 (Daejeon-si, Chungcheongbuk-do, and Chungcheongnam-do) comprised approximately 16.5% (n = 330); Region 4 (Gwangju-si, Jeollabuk-do, and Jeollanam-do) comprised 16.25% (n = 325); Region 5 (Gangwon-do) comprised 5.5% (n = 110); and Region 6 (Jeju Island) comprised 5% (n = 100).

The demographic composition of the respondents was 49.3% (n = 986) male and 50.7% (n = 1,014) female (Table 1). The respondents' ages were grouped into six categories: the first group, 15–29 years of age, comprised 8.9% (n = 178); the second group, 30–39 years of age, comprised 22.7% (n = 454); the third group, 40–49 years of age, comprised 22.7% (n = 454); the fourth group, 50–59 years of age, comprised 22.3% (n = 446); the fifth group, 60–69 years of age, comprised 16.85% (n = 337); and the sixth group, 70 years of age and older, comprised 12.15% (n = 243) of the total respondents.

4.2. WEEE discharge experience and item

Six-hundred and thirty respondents (31.5%) had WEEE discharge experience within the past year, while 1,370 respondents (68.5%) did not. Concerning demographic characteristics, such as gender, age, and region, the results can be summarized as follows. More male respondents (53.3%, n = 336) reported recent experience with WEEE discharge than female respondents (46.7%, n = 294). Respondents in the 50–59 age group (26.8%) expressed the highest rate of WEEE discharge experience, followed by the 40–49 age group (24.4%), the 60–69 age group (18.9%), the 30–39 age group (14.3%), the over 70 group (10.5%), and finally, the 15–29 age group (5.1%). The region with the highest rate of WEEE discharge experience was Region 2 (Pusan-si, etc.), scoring 30.48%. In decreasing order, the other regional results were as follows: Region 1 (Seoul-si, etc., 29.84%), Region 4 (Gwangju-si, etc., 15.24%), Region 3 (Daejeon-si etc., 14.44%), Region 6 (Jeju-si, 6.03%), and Region 5 (Gangwon-do, 3.97%) (Table 1).

The WEEE item most often discarded was a refrigerator (35.08%). The second most discarded item was a television (20.63%), followed by a washing machine (9.21%), computer (7.14%), microwave or oven (5.71%), and vacuum cleaner (5.08%). The next five categories each contributed to less than 5% of waste: radio or audio, electric cooker, air conditioner, fan, and printer or copier. Ten categories contributed to less than 1% of waste: air cleaner or humidifier, electric heater, dishwasher, water purifier, running machine, hairdryer, mixer, toaster, coffee machine, and massage chair (Table 2).

Table 2.
Respondents' WEEE discharge experience and specific item types.

Categories	Response	No. of Respondents	Percentage (%)
Discharge experience within 1-year (n = 2,000)[a]	Yes	630	31.50
	No	1,370	68.50
	Total	2,000	100.00
Item discarded (n = 630)	Refrigerator	221	35.08
	Television	130	20.63
	Washing machine	58	9.21
	Computer	45	7.14
	Microwave or oven	36	5.71
	Vacuum cleaner	32	5.08
	Radio or audio	19	3.02
	Electric cooker	17	2.69
	Air conditioner	16	2.54
	Fan	16	2.54
	Printer or copier	10	1.59
	Air cleaner	5	0.79
	Electric heater	4	0.63
	Dishwasher	3	0.48
	Water purifier	3	0.48
	Running machine[b]	3	0.48
	Hairdryer[b]	2	0.32
	Mixer	2	0.32
	Toaster[b]	1	0.16
	Coffee machine[b]	1	0.16
	Massage chair[b]	1	0.16
	Etc.[c]	1	0.16
	Don't remember	4	0.63
	Total	630	100.00

[a] The questionnaire concerned the year 2017 (running from Jan to Dec 2017).
[b] These electronic appliances will be included as EPR mandatory items in 2020.
[c] The products not mentioned in the above table were included in this group.

4.3. Preferred discharge routes

All respondents (n = 2,000) were asked to specify their preference of discharge routes based on the six routes and others (two options) (Table S2). The results show that 38.95% (n = 779) of respondents chose *local authorities (charged)* (Table 4). The next highest response was *take back* (37.30%, n = 746), followed by *personal recyclers* (10.15%, n = 203), *d-to-d service* (5.60%, n = 112), *transfer to others* (3.35%, n = 67), and *local authorities (free)* (2.00%, n = 40). *first option* ("*never thought*") (1.75%, n = 35) and *second option* ("*can't remember*") (0.90%, n = 18) made up the remainder.

The preferred discharge route appeared differed between male and female respondents. In decreasing order, male respondents preferred *local authorities (charged)* (40.97%, n = 404) and *take back* (33.27%, n = 328), but females preferred *take back* (41.22%, n = 418)and *local authorities (charged)* (36.98%, n = 375).

Overall, *local authorities (charged)* and *take back* routes were found to be preferred across all age groups. *Local authorities (charged)* was the route most preferred by those in their 20s (45.51%, n = 81), 30s (41.52%, n = 142), and 50s (39.46%, n = 176). The *take back* route was most preferred by those in their 40s (42.29%, n = 192), 60s (39.17%, n = 132), and over 70 (35.80%, n = 87).

From a regional perspective, respondents generally preferred the *local authorities (charged)* and *take back* routes more than the others. As can be seen in Table S3, the *local authorities (charged)* route was preferred in Region 2 (41.18%, n = 245), Region 4 (36.92%, n = 120), Region 5 (46.36%, n = 51), and Region 6 (40.00%, n = 44). Likewise, the *take back* route was most preferred in Region 1 (38.89%, n = 210) and Region 3 (38.49%, n = 127).

4.4. Actual discharge routes

Only respondents (n = 630) who had actual experience discarding WEEE in the preceding year (2017) were asked to report their discharge routes experience (Table S4). Overall, the most used discharge route was *local authorities (charged)* (27.46%, n = 173), followed by *take back*

(26.83%, n = 169), *d-to-dservice*(18.73%, n = 118), *local authorities (free)* (13.65%, n = 86), *transfer to others* (9.36%, n = 59), *personal recyclers* (3.65%, n = 23) and *other* ("can't remember") (0.32%, n = 2).

The 640 respondents with actual discharge experience consisted of 336 males and 294 females. Among them, the most frequently used discharge route differed by gender: males mainly used *local authorities (charged)*, and females mainly used the *take back* route (Table S4).

In terms of age, the *local authorities (charged)* route was mainly used by three age groups: under 29 years (43.75%), 30s (34.44%), and 50s (29.59%). The *take back* route was the most used by those in their 40s (28.57%), 60s (31.09%), and over 70 (39.39%).

Regionally, the *local authorities (charged)* route was the most used in four regions: Region 2 (29.69%), Region 3 (28.57%), Region 4 (28.13%), and Region 5 (40.00%). The *take back* route was most used in Region 1 (31.92%), and the *d-to-d service* route was most used in Region 6 (33.33%).

Although the *t*-tests of the difference in preferred discharge route between all respondents (n = 2,000) and respondents with actual discharge experience (n = 630) did not provide strong evidence of significance (Table S5), we can deduce some features by identifying a tendency in the variation of utilization rates between the two groups. First, the results showed that the *local authorities (charged)* and *take back* routes were preferred overall by participants. This trend was maintained even when respondents were classified by gender, age, and region. Another important feature is that the actual usage of the *local authorities (charged)* and *take back* routes was less that the expressed preference rate for these routes, while the actual usage of *d-to-d, personal recyclers*, and *local authorities (free)* was more than the expressed preference rate. The *Local authorities (charged)* route was preferred by 38.95% of total respondents in the preference survey, but actual usage was 11.49% less (27.46%). *Take back* was preferred by 37.30% of total respondents, but actual usage was 10.47% less (26.83%). In comparison, the routes with comparatively higher actual usage than preference were shown to be *d-to-d service* (preference: 5.60%; actual usage: 18.73%) and *local authorities (free)* (preference: 2.00%; actual usage: 9.36%) (Fig. 2).

4.5. Discharge characteristics by type of WEEE

Certain routes were used more often, depending on the type of WEEE. In the case of large-size appliances, a total of 425 respondents had disposed of large-size appliances within the preceding year. The most common discharge routes were *take back* (34.59%, n = 147), followed by *d-to-d service* (22.12%, n = 94), *local authorities (charged)* (20.94%, n = 89), *transfer to others* (14.82%, n = 63), *personal recyclers* (4.47%, n = 19), and *local authorities (free)* (3.06%, n = 13). For mid- and small-size appliances, a total of 205 respondents who had discharge experience of those items used *local authorities (charged)* most often (41.95%, n = 86), followed by *personal recyclers* (19.51%, n = 40), *d-to-d service* (11.17%, n = 24), *transfer to others* (10.73%, n = 22), *take back* (10.24%, n = 24), and *local authorities (free)* (4.88%, n = 10) (Fig. 3).

4.6. Cross-tabulation analysis

In the cross-tabulation analysis, differences in the actual discharge routes of respondents who had WEEE discarding experience were statistically analyzed with regard to the variables of age, region, and gender. In terms of age, four intergroup comparisons had strong evidence of significance at the 0.05 level, and one age intergroup comparison had significant evidence with a *p*-value of less than 0.10. Specifically, the under 29 age group significantly differed from three other age groups (40s, 60s, and over 70), with *p*-values of less than 0.05. Also, those in their 30s age group significantly differed from those in their the 60s ($p \leq$ 0.10) and those over 70 ($p \leq$ 0.05). Both those under 29 years and those in their 30s tended to use the *local authorities (charged)* and *take back* routes when discarding WEEE, but those in their 60s and those over 70 years tended to dispose of WEEE using the *take back* route (Table 3).

Some statistical differences in the actual discharge routes used by respondents were identified in terms of the region. Two intergroup comparisons had a significant difference with *p*-values of less than 0.05, and two other intergroup comparisons had significant differences with *p*-values of less than 0.10. Region 1 (Seoul-si, etc.) had strong evidence of significance with Region 2 ($p \leq$ 0.10), Region 5 ($p \leq$ 0.05), and Region 6 ($p \leq$ 0.05). Region 2 (Pusan-si, etc.) differed significantly from Region 3 (Daejeon-si, etc.) with a *p*-value of less than 0.05. Region 1 tended to dispose of WEEE using the *take back* and *personal recyclers* routes, but Regions 5 and 6 tended to use the *take back* and *local authorities (charged)* routes (Table 3).

There was no strong evidence of significance of the WEEE discharge routes used in terms of gender with respect to respondents (n = 630) who had discharge experience in 2017 (p = 0.170; Chi-squared value, x^2 = 9.069).However, the survey results on respondents' (n = 2,000)

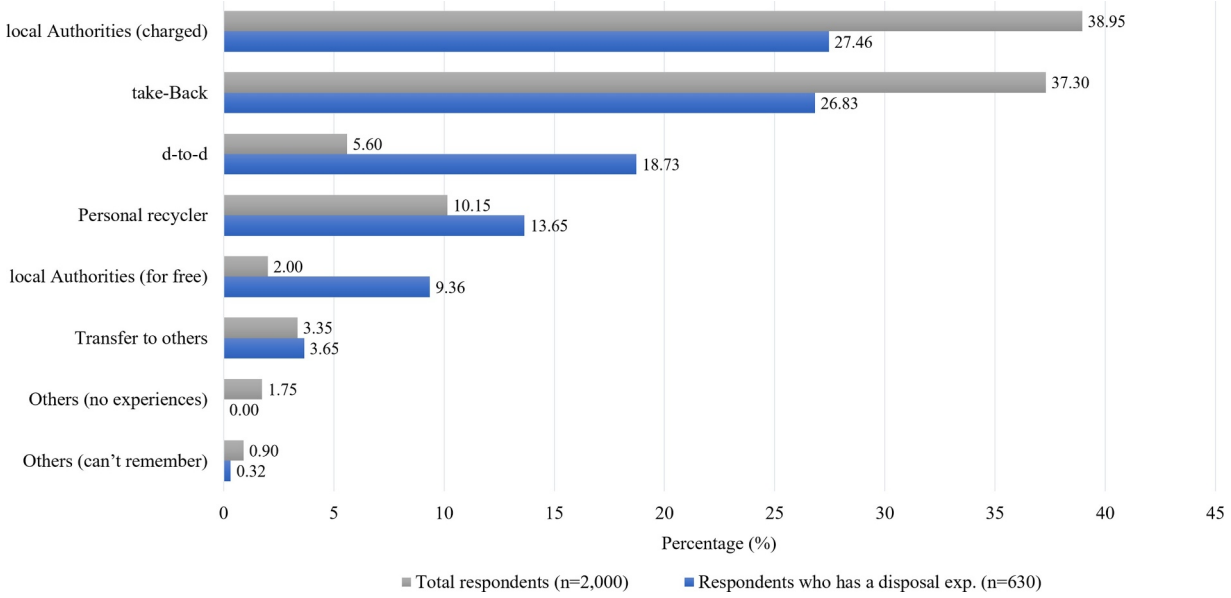

Fig. 2. Comparing the respondent's ratio (%) between preferred (n = 2,000) and actual (n = 630) WEEE discharge routes in 2017.

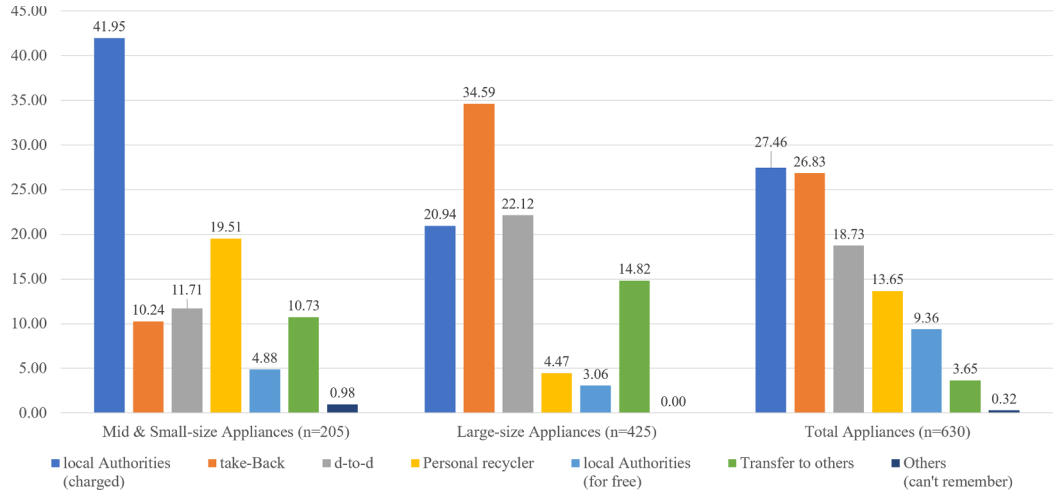

Fig. 3. Summary of routes used in relation to appliance size by respondents who had disposed of WEEE in the preceding year (2017).

preferred discharge routes were significantly different with *p*-values at the level of less than 0.001 (x^2 = 25.394) (Table 4). According to a post-hoc tests that compared each route depending on gender using the Bonferroni method, the differences in preference showed that three intergroup comparisons had strong evidence of significance: *D-to-D service* and *personal recyclers* ($p \leq$ 0.05, mean difference = 0.183), *local authorities (charged)* and *take back* ($p \leq$ 0.05, mean difference = -0.079), and *take back* and *personal recyclers* ($p \leq$ 0.01, mean difference = 0.181).

According to the post-hoctest for the cross-tabulation analysis in terms of gender, between *d-to-d service* and *personal recyclers* ($p \leq$ 0.05), female respondents had a relatively stronger preference for *d-to-d service* compared to male respondents. In another intergroup comparison between the *local authorities (charged)* and *take back* routes ($p \leq 0.05$), female respondents showed a stronger preference for *take back* compared tomale respondents. Similarly, the female respondents had a stronger preference for the *take back* route over the *personal recyclers* route compared to male respondents ($p \leq$ 0.01). Thepost-hoc test showed that the female respondents had a stronger preference than male respondents for the *take back* and *d-to-d service* routes compared to the other routes.

4.7. Descriptive statistics for the TPB model

For the TPB model, four independent variables (*attitude, subjective norm, perceived behavioralcontrol,* and *behavioral intention*) and two dependent variables (*actual discharge behavior* and *actual discharge route*) were collected from all the respondents (n = 2,000). Table S6 shows the descriptive statistics (min, max, mean, and standard deviation) for all variables. The attitude, perceived behavioral control, and behavior intention variables were rated using a 5-point Likert scale; the mean and standard deviation values were 2.33 (± .025), 4.29 (± .019), and 4.28 (± .019), respectively. Meanwhile, the subjective norm variable used a 3-point scale and showed a mean value of 1.68 (± .018). The mean values of actual discharge behavior and actual discharge route, expressed in binary terms, were 1.69 (± .010) and 1.45 (± .499), respectively.

Table 3.
Cross-tabulation analysis for actual WEEE discharge routes in terms of age and region.

		Age Groups[a]					Region Groups[b]					
		< ~29	30s	40s	50s	60s		R1	R2	R3	R4	R5
x^2	30s	9.213 (.162)					R2	12.374** (.089)				
	40s	14.2380* (.014)	6.571 (.362)				R3	9.099 (.105)	10.755** (.096)			
	50s	7.535 (.184)	8.435 (.134)	3.39 (.640)			R4	7.228 (.300)	3.522 (.741)	3.594 (.731)		
	60s	12.0580* (.034)	11.364** (.078)	3.631 (.604)	3.815 (.576)		R5	11.807* (.038)	4.311 (.632)	8.435 (.134)	5.204 (.518)	
	> ~70	12.862* (.045)	13.958* (.030)	9.115 (.167)	9.718 (.137)	4.043 (.671)	R6	16.442* (.006)	8.985 (.174)	4.506 (.479)	5.633 (.466)	5.337 (.376)
Age	< ~29	30s	40s	50s	60s	> ~70	Region	R1	R2	R3	R4	R5	R6
Mean (3.087)	2.625	2.744	2.955	2.899	3.151	4.149	Mean (2.801)	3.218	2.984	2.681	2.938	2.640	2.342
Number	1.00		2.00		3.00		4.00	5.00		6.00		7.00	8.00
Channel	D-to-D		L.A.(c) [b]		T.B.[c]		P.R.[d]	Trans. [e]		No exp.[f]		L.A.(f)[g]	No rem.[h]

[a] The two groups of the total age group were set as rows, and the discharge routes were set as columns in SPSS.
[b] The two groups of the total region group were set as rows, and the discharge routes were set as columns in SPSS.
[b] *Local authorities* (*charged*). [c] *Take back.* [d] *Personal recyclers.* [e] *Transfer to others.*
[f] *No experience* (discarding WEEE). [g] *Local authorities* (*free*). [h] *Don't remember.*
* *p*-value ≤ *.05,* ***p*-value ≤ *.10.*

Table 4.
Cross-tabulation analysis for WEEE discharge routes in terms of the Gender; This cross-analysis was performed on two samples (total respondents and respondents who had actual discharge experience).

Category		Discharge Routes							Chi Squared
Discharge exp. (n = 630)		Local Authorities (Charged)	Take Back	D-to-D	Personal Recyclers	Local Authorities (Free)	Transfer to Others	Others	x^2
Gender	Male	96 (28.6%)	89 (26.5%)	54 (16.1%)	53 (15.8%)	34 (10.1%)	10 (3.0%)	0 (0.0%)	9.069 (.170)
	Female	77 (21.8%)	80 (27.2%)	64 (21.8%)	33 (11.2%)	25 (8.5%)	13 (4.4%)	2 (0.7%)	
	Total	173 (27.5%)	169 (26.8%)	118 (18.7%)	86 (13.7%)	59 (9.4%)	23 (3.7%)	2 (0.3%)	630 (100.0%)
Total (n = 2,000)									
Gender	Male	404 (41.0%)	328 (33.3%)	49 (5.0%)	126 (12.8%)	20 (2.0%)	34 (3.4%)	25 (2.5%)	25.394* (.001)
	Female	375 (37.0%)	418 (41.2%)	63 (6.2%)	77 (7.6%)	20 (2.0%)	33 (3.3%)	28 (2.8%)	
	Total	779 (39.0%)	746 (37.3%)	112 (5.6%)	203 (10.2%)	40 (2.0%)	67 (3.4%)	53 (2.7%)	2,000 (100.0%)

* p-value ≤.05.

4.8. Regression analysis for the TPB model

Regression analysis was conducted to verify the significance between behavioral intention and the three beliefs: respondent's attitude, subjective norm, and perceived behavioral control. The results showed that two variables, subjective norm ($p \leq 0.01$) and perceived behavioral control ($p \leq 0.01$), had significant effects on the dependent variable (behavioral intention), but attitude did not have a significant effect ($p = 0.198$) on behavioral intention. From the above regression, we found not only that respondents had a stronger behavioral intention to dispose of WEEE using the formal sector, but also that this agreed with their subjective norm that the government and society should encourage this behavior ($B = 0.215$, $p \leq 0.001$). Similarly, the stronger the behavioral intention of the respondents, the more they perceived and agreed with their control capacity to discard WEEE through the formal sector themselves ($B = 0.376$, $p \leq 0.001$). Regarding the respondents' attitudes, they understood that WEEE needed to be discarded through the formal sector, and that did not affect their behavioral intention to discard the WEEE in the formal sector (Table 5).

We analyzed how perceived control of the discharge of WEEE through the formal sector affected actual WEEE discharge behavior. Table 5 shows that perceived behavioral control significantly affected actual discharge behavior in the logistic regression analysis ($B = 1.351$, $p \leq 0.001$). As perceived behavioral control increased by one point, the probability of the non- discharge of WEEE in respondents' daily lives increased 3.859 times (Exp (B)) = 3.859); this implies that the higher the respondent's perceived control of WEEE discharge through the formal sector, the less likely they were to have experience discarding WEEE.

Finally, we analyzed how perceived controlaffects actual discharge routes. We focused on two conditions in the analysis stage: First, we considered only the 630 respondents who had actual WEEE discharge experience in the last year (2017). Second, only two discharge routes, *take back* and *d-to-d service,* were considered as belonging to the formal sector (n = 287, 45.6%). Simultaneously, the other routes were considered as belonging to the informal sector (n = 343, 54.4%). Table 5 shows that perceived behavioral control significantly affected actual discharge routes, based on the result of the logistic regression ($B = 0.846$, $p \leq 0.05$). This result indicates that if perceived control increased by one point, the probability that the respondent disposed of WEEE through the formal sector (*take back* and *d-to-d service)* in their daily life increased 2.331 times (Exp (B)) = 2.331). Thus, the higher the respondent's perceived control of the discharge of WEEE through the formal sector, the more likely they were to discard WEEE through the formal sector in reality.

Table 5.
Regression and logistic regression analysis results used to identify decisive factors affecting behavioral intention and actual behavior.

Independent var.	Behavioral intention (regression)[d]			
	B	S.E.	t-value	p-value
Attitude[a]	0.022	0.017	1.288	.198
Subjective norm[b]	0.215***	0.024	8.999	.000
Perceived behavioral control[c]	0.376***	0.021	17.566	.000
Constant	2.255***	0.109	20.732	.000
	Actual discharge behavior (logistic regression)[e]			
	B	S.E.	Exp(B)	p-value
Perceived behavioral control[c]	1.351***	0.262	3.859	.000
	Actual discharge route (logistic regression)[f]			
	B	S.E.	Exp(B)	p-value
Perceived behavioral control[c]	0.846*	0.433	2.331	.050

[a] A belief's likely consequence or other attributes of the behavior.
[b] Beliefs about the normative expectations of other people.
[c] The presence of factors that may further or impede the potential performance of the behavior.
[d] Identifying significant effects between three beliefs and behavioral intention.
[e] Identifying significant effects between the control belief and the actual discharge behavior.
[f] Identifying significant effects between the control belief and the actual discharge route.
* p-value ≤.05, **p-value ≤.01, ***p-value ≤.001.

5. Conclusion

The purpose of this study was to investigate and analyze the behavioral characteristics of consumers when disposing of end-of-life home appliances and to suggest alternative approaches for entering a resource-circulation society through the establishment of various strategies to increase the volume of WEEE collection. This study was conducted in 2017, using the CATI survey method to target and consider the characteristics of 2,000 respondents throughout South Korea. It focused mainly on respondents' preferred and actual WEEE discharge routes and their connection with the social characteristics of age, region, and gender. Furthermore, this study compared consumer discharge behavior with the respondents' beliefs, such as their attitude toward behavior, subjective norms, and perceived behavioral control based on the TPB. Using regression and logistic regression analysis, we identified how the respondents' beliefs were affected by their behavioral intention and how their perceived control affected their actual behavior.

Our findings revealed that refrigerators and TVs account for more than 55.71% of the end-of-life appliances being disposed of. This implies that the MOE and stakeholders, including recycling plants, in South Korea need a plan for the future because the internal volume of refrigerators is expanding due to the use of more vacuum insulation panels. Other materials are also changing, such as R600a (isobutane),

which uses eco-friendly refrigerants with close to zero global warming potential. Also, light emitted diode (LED) and organic light emitted diode (OLED) TV products may account for a significant portion of recycling in the future—possibly more than current cathode-ray tubes. In response to the changing trends related to these products and components, the MOE and stakeholders in WEEE recycling should continue to create regulations and build facilities suitable for reducing environmental risk and the waste of resources.

Three main conclusions can be made regarding the discharge characteristics identified in this study. First, the reason that the actual usage of *d-to-d* was higher than preference is likely because the *local authorities (charged)* and *take back* routes were relatively difficult for the respondents to access. In other words, the use ofthe *local authorities (charged)* route for discharge was inconvenient due to the need to buy and attach governments-issued stickers to waste, and the *take back* route only allows consumers to discard obsolete products when they purchase new products. It can be inferred, then, that the rate at which zero-cost *d-to-d service* is used in reality is improved.

Second, the use of *take back* and *d-to-d service* was relatively higher for large-size appliance collection. These routes are characterized by a high level of consumer convenience, because the collection engineer directly visits the home, comes inside, and takes charge of dismantling and collecting, making these routes highly advantageous for collecting large-size appliances. At the same time, the *local authorities (charged)* route was preferred for WEEE collection by respondents who had experience discarding mid- and small-sized e-waste. Unlike *take back* and *d-to-d service*, the *local authorities* route requires that consumers bring their waste electronics outside of their house. The results indicate that the *local authorities* route is suitable for disposing of light appliances that do not require removal and collection by professional technicians.

Finally, the usage of the *personal recyclers* route was higher in Region 1 and in the over 70 age group. This is probably because the heavily populated areas of Region 1 are able to generate sufficient revenue for personal recyclers. Also, personal recyclers can be particularly useful to elderly respondents with limited mobility.

The regression analysis using the TPB model showed that subjective norm and perceived behavioral control significantly affected behavioral intention, but attitude did not have a significant effect on behavioral intention. This result suggests that consumers may focus more on convenience, actual opportunities, and other factors than on their own attitude towards discarding WEEE through the formal sector or on actual discharge steps. Thus, e-waste management strategies that recognize consumers' moral norms and behavioral control aspects should be developed using education or public relations to encourage consumers to discard e-waste through the formal sector.

The logistic regression analysis found two implications: consumers with a strong control belief were less likely to have less actual WEEE discharge experience but were more likely to discarded WEEE through the formal sector. Based on these results, we can infer that South Korean society has reached a high level of civil consciousness regarding the proper discharge of e-waste. In order to continue the proper collection and recycling of WEEE through the expansion of the formal sector, we suggest implementing strategies that emphasize consumers' perceived and motivated control beliefs.

6. Discussion and limitations

6.1. Discussion

One of the significant implications of this study is that our research results, which are derived from the TPB, provide cognitive validity for the discharge and recycling of e-waste in South Korean society. Because we minimized the error of the biased response, could result from the negative perception for the informal sector, by excluding the provision of prior information on whether or not an arbitrary discharge route is informal. In other words, by not defining what discharge routes are considered part of formal and informal sectors, we avoided artificial errors in answers that could occur if such information was provided. However, future research is needed to determine if the public can distinguish between formal and informal discharge and recycling methods and decide which is better from an environmental perspective.

In previous studies relevant to WEEE management, different variables were identified through analysis of consumer behavior using the TPB as being the most important. While some mentioned perceived behavioral control as being the most important factor of WEEE recycling behavioral intention, others emphasized subjective norm or attitude. Our results suggest that perceived behavioral control and subjective norm were meaningful predictor variables, affecting behavioral intention for the discharge WEEE through the formal sector. The reason why perceived behavioral control was chosen as the most important predictor was that South Korea has a formal sector, which includes the *take back* and *d-to-d* free pickup system (http://www.edtd.co.kr), and people potentially recognize these formal routes due to mass media and publicity campaigns. Where a formal sector exists, as in South Korea, discharging e-waste through the formal sector through perceived control beliefs can be regarded as a routine that is easily accessible. In contrast with South Korea, the significance of perceived control beliefs was relatively decreased in case studies conducted in countries where a formal sector did not exist (Boldero, 1995; Davies et al., 2002; Nduneseokwu et al., 2017).

In addition, the reason why subjective norm was chosen as a significant variable can be inferred as follows: WEEE recycling has become a social norm, and peoples' awareness and participation achievement (37.5% in 2017) can be classified as higher in South Korea than in other countries (35% in Europe and 15% in Asia as of 2017) (Balde et al., 2017). Kumar (2019) suggest that a high level of social norm for formal sector discharge of e-waste could be translated into a cultural norm. This implies that the subjective norm of e-waste recycling has already become a cultural norm in South Korea; therefore, the subjective norm is considered a significant predictor variable.

According to the analysis results for social factors (control variables) presented in Table S7, a strong behavioral intention to discharge e-waste through the formal sector was identified in non-metropolitan, small town, and rural areas, but these geographical features did not lead to the actual discharge behavior. Furthermore, in the case of actual discharge, geographical features did not contribute to people's selective discharge through the formal sector. To solve this problem, policy strategies should be established for government and electronics manufacturers to achieve quantitative goals by expanding *take back* and *d-to-d service* in small towns and rural areas. In addition, local governments in these regions should adapt "publicization" in the WEEE storage or separation steps, excluding private persons or companies, at the local government's management sites so that WEEE collected and transported through the local authority route is recycled as a formal sector.

Since a preference for formal sector e-waste disposal was observed in older and female respondents, the following promotion strategies should be directed at young and male respondents. First, students can be provided with a mandatory allocation of educational time to circulate resources in schools (elementary, middle, and high school). Second, considering the current status of the South Korean domestic labor statistics, can be established based on the gender ratio of South Korean domestic labor (69.9% male and 92.9% female) provided by the Ministry of Gender Equality and Family in 2015, male are relatively less interested in household labor that discharging the e-waste. In other words, promoting the importance of proper e-waste discharge in the workplace because men are less likely to be responsible for domestic e-waste discharge and disposal.

A future survey could focus specifically on a particular demographic group or discharge route–using subset while also expanding on the exploration of the TPB concepts with regard to their use. It could also be argued that the customization of the collection system with appropriate

promotional activities and education is necessary. This should consider the physical features of the type of WEEE and the social characteristics of consumers who are willing to discard it, in order to maximize collection efficiency. At the same time, it is necessary to establish and implement plans to improve the social norm and behavioral control aimed at the consumer.

6.2. Limitations

Although the general and analytical results were well interpreted and correspond with those of past studies that have used the TPB, this study had some limitations. The first limitation is that, because our research reviewed the influences on behavioral intention to participate in a formal sector on a nationwide scale in South Korea, our conclusions and implications may not be generalizable to other countries.The second limitation is that the concepts of attitude, subjective norm, perceived behavioral control, and behavioral intention were queried with a minimum of questions. This is a concern, as a minimum number of items may not be able to detect change. In our case, effects were found; thus, the items seemed to function adequately. However, we acknowledge that more questions on these concepts would provide a more detailed view.

One point of weakness with respect to the survey method is that there is not enough evidence to represent the measurement of social desirability biases and minimization results for the CATI survey approach. We attempted to minimize biases in interaction and sampling by hiring an interviewer who specialized in the CATI method and implementing stratified sampling. However, there is not enough evidence to quantify biases because we did not conduct face-to-face and CATI surveys simultaneously. Despite this weakness, the main purpose of this study was not to analyze biases between face-to-face with CATI methods; thus, the comparative quantification of social desirability biases is left to be revealed in a further study.

In addition, follow-up studies are needed to attempt to quantify the amount of e-waste discharged in the informal sector in South Korea because estimating WEEE in the informal sector has thus far been uncertain and difficult. According to global reports, approximately 665 thousand tons of e-waste might be generated in South Korea (Korea Electronics Recycling Cooperative 2019). In the same manner, the MOE estimates approximately 661 to 662 thousand tons in 2016. However, since the MOE's research contains confidential data, there are limitations to the discloser of its results and methodologies. As a result, we must continue to attempt to estimate the amount of WEEE in the informal sector.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Supplementary materials

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