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Electrical and electronic equipment repair in a circular economy: Investigating consumer behaviour in Hong Kong

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ABSTRACT

The circular practice of repair extends the lifetime of electrical and electronic equipment (EEE) and thus decreases their environmental impact. This investigation centres on Hong Kong, which features a high per-capita consumption of electronics, and explores what factors drive consumer behaviour intention to repair EEE. In terms of materials, a Likert-scaled questionnaire survey was conducted among Hong Kong consumers (n = 609). This data was treated via an extended model of the Theory of Planned Behaviour (TPB) incorporating the factors 'awareness of consequences', 'environmental concern 'and 'policy concern'. The extended TPB model features a strong predictive power (54 %) for behavioural intention to repair, on which environmental concern (β = 0.473***) and perceived behavioural control (β = 0.224***) had the strongest influence. Policy concern (β = 0.068ns), however, turned out to be statistically insignificant. This provides critical insights on the factors that policy and research need to further explore for strengthening circular economic consumer behaviour in Hong Kong.

1. Introduction

Globally, the electronics industry is the largest and fastest-growing manufacturing sector (Clarke et al., 2019). Yet, the fast obsolescence of modern products has resulted in a significant rise in used Electrical and Electronic Equipment (EEE) and Waste Electrical and Electronic Equipment (WEEE) (Clarke et al., 2019; Kumar, 2017). Increased WEEE generation has in turn raised pollution levels of ecosystems on land and under water through the uncontrolled release of heavy metals and hazardous substances (Castro and Bassin, 2022; Hassan et al., 2023; Twagirayezu et al., 2022). Improper disposal and recycling patterns also pose hazards to human health, especially (unborn) children, pregnant women, and unprotected recyclers (Alabi et al., 2021). Resource extraction for and manufacturing of electronics itself are extremely material- and energy-intensive, entailing greenhouse gas emissions and social and health-related issues (Heacock et al., 2016). From a sustainable development perspective, these negative impacts are increasingly hard to justify in light of electronics' relatively short lifetime. To tackle these issues, sustainable resource management approaches, policies and regulations are indispensable. For used EEE and WEEE, particularly the adoption of circular economy (CE) practices such as urban mining, product-life extension and the improvement of supportive policies can entail significant environmental benefits (Abalansa et al., 2021; Ghosh et al., 2022; Taqi Ghulam and Abushammala, 2023). Recent studies underscore the significance of applying the CE's "R" principles, e.g., refuse, reduce, reuse, repair, refurbish, recycle, etc., to conserve resources, minimize waste and reduce environmental impacts. Although recycling continues to be the CE's most practiced pattern (Hunger et al., 2024; Zimmermann et al., 2024), other practices such as repair, reuse, and remanufacturing are gradually being recognized (King et al., 2006; Pan et al., 2022) after a long period of neglect of these effective circular solutions.

In this sense, the CE strategy of extending the electronic product life through repair entails environmental gains (Bachér et al., 2020; Bakker and Schuit, 2017; Leyvraz, 2021; Rudenauer and Prakash, 2020) and promises to boost local economies (Llorente-González and Vence, 2020). Moreover, it may bring back a product-associated lifestyle centred on caring and valuating product ownership (Bovea et al., 2017; Montalvo et al., 2016). For instance, the Framework Laptop is designed with the aim of facilitating repair, swapping or upgrading components and thereby extending the lifespan of the laptop (Framework, 2024). Likewise, the Fairphone enables do-it-yourself (DIY) repairs via the long-term provision of spare parts. Similar to the Framework Laptop, the Fairphone's value proposition centres on extending product lifetime,

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which in turn reduces its environmental footprint (Fairphone, 2020). In general, the advantages of repair over recycling are the reduced deformative effects on product and material functionality, which entail enhanced value retention, reduced energy intensity, and more employment opportunities, particularly for unemployed urban labour. Yet, to enable a sustained operation of such circular systems around EEE repair, refurbishment and manufacture, regulations and standards for safety standards and product warranties are indispensable.

The notion of consumer behaviour towards WEEE has garnered interest in research alongside the concept of the CE. Initial contributions emerged in 2010 and featured a notable increase after 2018, resulting in over 100 research works to date (Islam et al., 2021; López Dávila et al., 2021; Niskanen et al., 2021). Islam et al. (2021) conducted an extensive analysis of 109 research publications concerning consumer behaviour towards WEEE, which identified research deficiencies and provided a consumer-oriented CE for policymakers and researchers. The study found that consumers' disposal and recycling behaviours are the two main areas of research interest, while reuse and repair behaviour were investigated to a lesser extent. Additionally, Islam et al. (2021) highlighted that improving consumer awareness through education and advertising, particularly via social media and physical locations as critical. Newaz and Appolloni (2023) performed a bibliometric and content analysis of 293 articles about behavioural studies on WEEE. It identified two primary clusters: 'CE behaviour' and 'behavioural overflow', each encompassing separate study topics and streams. The study found that the theory of planned behaviour (TPB) has become the principal concept extensively employed and elaborated on in research examining return and recycling patterns. The study suggested future research directions, highlighting the necessity for a theoretical integration or expansion of the TPB to better understand this domain.

Despite the growing scientific and policy interest in repair (Ackermann et al., 2018; Cerulli-Harms et al., 2018; Islam et al., 2021; Raihanian Mashhadi et al., 2016; Scott and Weaver, 2014; Wieser and Tröger, 2018), inquiries into consumers' motivation to engage in repair is still marginal. The current article strives to close this gap by investigating how in the little explored environment of the Hong Kong Special Administrative Region (HKSAR) psychological-behavioural factors, such as attitudes, norms and routines influence an individual's decision to repair electronic devices.

2. Overview on circular economy practices in Hong Kong

2.1. Challenges for WEEE recycling in Hong Kong

Hong Kong encounters considerable difficulties in managing WEEE. In the past, Hong Kong's long-term practice of exporting recyclable waste (WEEE among it) to the mainland was not conducive towards developing CE structures within the city (EPD, 2023; Steuer, 2022). Yet, due to gradually tightening waste import restrictions in Mainland China since 2016, this pathway gradually eroded (BEC, 2021; Steuer, 2022). As exporting WEEE became increasingly difficult, the Hong Kong government has taken measures to address the challenge locally by implementing the 2018 Producer Responsibility Scheme for WEEE (WPRS). In doing so, parts of the WEEE stream are to be processed within Hong Kong thereby extracting valuable secondary materials. However, due to the lack of manufacturing industries in Hong Kong, there is no local demand for recycled materials. Alternatively, selling these internationally would face a weak cost-competitiveness due to high local labour costs.

Moreover, the implementation of the WPRS merely resulted in the recovery of 31 % (21,344 tonnes) of products placed on the market. Thereof, the sole formally registered recycling plant (WEEE.PARK) managed about 80 % (18,470 tonnes) in 2022 (ALBA, 2022; EPD, 2023). These figures are however only a fraction of the eight product categories of Regulated Electronic Equipment (REE) (AC, washing machine, refrigerator, TV, computer, monitor, printer, and scanner) covered by the WPRS. The much larger remainder as well as other device categories such as mobile phones or tablets are repaired and refurbished for reuse by a network of unregistered repair and trading shops (Koniordou and Laird, 2018). The absence of a comprehensive recycling infrastructure with efficient reverse logistics, the inadequate regulatory framework and the exclusion of informal operators impede effective management of WEEE in Hong Kong. In light of the above, recycling alone does not appear to be a viable strategy for managing EEE in Hong Kong.

2.2. Challenges for EEE repair in Hong Kong

According to the Hong Kong Environmental Protection Department (EPD), the Hong Kong government mainly focuses on EEE and REE the take-back system and recycling instead of providing repair and refurbishment. Yet, there are stakeholders involved in (W)EEE repair which include households, e-waste collectors, companies, logistics services, and second-hand e-waste traders. Second-hand e-waste traders also operate repair and refurbishment shops, which instead of recycling give priority to the refurbishment of collected items for resale on the second-hand market (Lau et al., 2013). Second-hand EEE, exempt from the Waste Disposal Ordinance, must be appropriately stored and accessible for inspection by relevant authorities. The EPD may require certified second-hand e-appliance dealers, waste traders, recycling site operators, importers or exporters to provide evidence demonstrating that second-hand EEE is suitable for direct reuse. An earlier study on the situation in Hong Kong highlighted that 75 % of TWARC (TV, washing machine, air-con, refrigerators and computers) handled by repair shops were resold on the second-hand market, while the remaining TWARC collected by scrap metal collectors, were assumed to be exported for material extraction (ibidem). However, a thorough evaluation of repair activities and the sale of second-hand electronic products has not yet been conducted.

These repair services encompass both small and large electronic devices, highlighting a considerable demand for experienced technicians. The participation of informal traders may result in difficulties with quality control and adherence to safety requirements, necessitating consumers to practice discretion when choosing repair services. Moreover, it may also cause secondary pollution stemming from repairs and improper disposal (Apprey et al., 2024). Another challenge is that the repair market faces significant limitations due to the high cost of genuine replacement parts, design issues and consumer perceptions (Allied market research, 2023; Exactitude, 2024). These challenges likewise affect Hong Kong's repair shops, which are additionally burdened by technological viability constraints due to lacking environmental design, challenging assembly or highly fragile components (Fan et al., 2016).

2.3. Repair practices of consumers and the "right to repair"

Unlike regions such as the European Union (EU), Hong Kong lacks legal measures in support of consumers' rights to repair (Hong Kong Lawyer, 2021). This absence means consumers face difficulties in obtaining necessary parts and information for repairs, often leading them to discard defective products instead of repairing these for extended use. Generally, access to repair services and practices are in most countries still met with many constraints (Bridgens et al., 2018). Past research asserted that consumers often lack abilities (e.g., time, skills, knowledge) and motivation (e.g., financial, social, idealistic value) to submit devices to repair services (Ackermann et al., 2021; Fachbach et al., 2022; Jaeger-Erben et al., 2021). Conversely, consumers in high income countries engaging specialists for repair generally face relatively high costs rendering repair non-competitive compared to buying new products (Brusselaers et al., 2019; van den Berge et al., 2022). Another challenge is planned obsolescence, a business strategy, where producers intentionally (re)design products to feature shortened lifespans and thus nurture future demand (Cooper and Salvia, 2018;

Fachbach et al., 2022). Finally, Makov and Fitzpatrick, (2021) pointed out time-related barriers implying the decline in interest to repair devices later in their lifecycle.

To counter these patterns via government legislation is critical and recent legal developments indicate that global CE frameworks in favour of EEE repair and refurbishment are in fact expanding. This is for example demonstrated by the EU's parliament voting in favour of the right-to-repair for common goods, including household electronics in late 2023. It stipulates a ban on any producer-designed measures obstructing repair and the obligation for sellers and manufacturers to prioritise repair over product replacement (EEB, 2023). This development arose from the EU's new circular economy action plan that assigns a key focus on electronics and which triggered a series of regulations, including the Ecodesign for Sustainable Products Regulation (ESPR) and the Directive on the Repair of Goods (entered into force on 30 July 2024) (European Commission, 2024). Among its key features is the obligation to repair, which applies to manufacturers of electronic products. To support this measure, the EU plans to implement an European Online Platform for repair in 2027, which will enable consumers to find repair services more easily and cost-effective due to an extension of the legal guarantee after repair (European Commission, 2024). The EU is further expected to follow the French example and introduce an EU-wide repairability index for smartphones and tablets by 2025 (HKTDC, 2024). France has recently gone one step further and will replace its 2021 "repairability index" with a refined "durability index" that provides information on robustness and reliability in 2025 (European Commission, 2024). The US initiated campaigns against repair restrictions (Federal Trade Commission, 2021) and some countries introduced subsidies for repair services such as Austria's Repair Bonus (Lechner et al., 2021). Similarly in China, legal measure on the repair, reuse, refurbishment and remanufacturing of electronics is tacitly increasing. Two policy measures are particularly notable. First, the 2020 Plan to Revitalise Recycling and Consumption of Household Appliances outlining ideas for the development of formalised, regulated repair, refurbishment and remanufacturing services for electronics. Second, the 2021 Notice on the CE Development Plan under the fourteenth Five-Year Plan emphasiaes the regulatory standardisation of second-hand markets for household appliances and mobile phones among other consumer goods (Steuer, 2022). However, for the case of Hong Kong, steps in this direction are as of now still outside of the legislative debate (Lee, 2021).

3. Research significance and objectives

While consumers are a major source of WEEE generation, there is as of now still a huge shortcoming regarding disposal choices vis-à-vis circular behaviour in Hong Kong. Be that globally or in Hong Kong, it is important to understand what factors influence residents' behavioural intentions for repairing vis-à-vis discarding electronics. In light of the challenges and research gaps, two research questions are guiding this study: What is the disposal pattern of household WEEE generation, and which psychological factors influence consumer repair behaviour in Hong Kong? The study thus seeks to explore Hong Kong consumers' motivation to repair EEE. Specifically, it aims to identify the use of different discard and repair channels vis-à-vis the context-specific psychological factors that drive consumers to repair or discard electronic products. As the findings specifically outline the case of Hong Kong, a high-income city, they in turn enable comparisons to repair practices in similarly affluent regions and by extension help narrow existing research gaps. Based on the behavioural patterns we further develop a set of policy recommendations to local decision-makers in the sense of strengthening the legal and policy related standing of the local CE. In the subsequent sections, we first discuss the analytical framework (Section 4), including TPB model development in the context of environmental studies (Section 4.1), research hypotheses and relevant control variables (Section 4.2) as well as data collection and statistical analysis procedures (Section 4.3). The research results are presented in Section 5, discussed in Section 6 and translated into theoretical, practical and policy implications in Section 7. The study's overall novelty and contribution to the existing body of research will also be summarised in Section 8.

4. Materials and methods

4.1. Research model development

Research on the relationship between behaviour and waste management has produced a notable body of literature employing different theoretical perspectives (Newaz and Appolloni, 2023). For example, work on household recycling behaviour has assessed the correlations among diverse contextual and psychological variables using theories such as the TPB, Behavioural Reasoning Theory (BRT), and Valence Theory (Newaz and Appolloni, 2023). Existing literature using the TPB in waste management predominantly focuses on consumer behaviour and intentions behind e-waste recycling (Aboelmaged, 2020; Bhutto et al., 2023; Islam and Huda, 2020; Koshta et al., 2022; Kumar, 2019; Poškus, 2015), food waste preventing (Aydin & Aydin, 2022; Russell et al., 2017; Wong, 2018) and anti-littering behaviour (Ibrahim et al., 2021). Although there are studies on consumer behaviour in EEE repair such as for consumer perspectives on the right to repair (Baker et al., 2022; Marikyan and Papagiannidis , 2024) and on the willingness to repair EEE (Fachbach et al., 2022; Pérez-Belis et al., 2017; van den Berge et al., 2022; van den Berge et al., 2023), only a few have applied the TPB to investigate drivers behind repair behaviour. Likewise, for the case of Hong Kong, the use of TPB to investigate EEE or WEEE management is a novelty. Some work has applied TPB to forecast behavioural intention in the city, such as for health (Li et al., 2022; Ng et al., 2022), plastic waste minimisation (So et al., 2021), construction waste recycling (Mak et al. (2018) and dishonesty in academic contexts (Kam et al., 2018). In light of that shortcoming, our research resorted to conceptualisations outlined in international (W)EEE-centred TPB studies, which roughly include explorations of consumers' intention to repair and reuse (Davila et al., 2021; Fachbach et al., 2022; ; Parajuly et al., 2023; Pérez-Belis et al., 2017) and recycling patterns (Islam and Huda, 2020; Koshta et al., 2022; Kumar, 2019; Newaz and Appolloni, 2023).

The rationale for using TPB stems in this research stems from its ability to explain people's intentions to execute a particular behaviour (Jokonya, 2017; Tornikoski and Maalaoui, 2019). According to the original theory first put forth by Ajzen (1991), three main factors influence behavioural intention: Attitude (ATT), subjective norms (SN), and perceived behavioural control (PBC). Building on these, TPB provides a thorough framework for assessing several socio-psychological categories of behaviour that are mostly determined by behavioural intention (BI), which again is shaped by ATT, SN and PBC (Ajzen, 1991). The TPB asserts that a stronger BI has a higher likelihood to induce the execution of a behaviour. As theory, TPB thus emphasizes BI as the key precursor to action. Hence, in the present study, a TPB construct is used to approximate how EEE repair behaviour in Hong Kong unfolds.

For the model design, considering predictive power is vital for effective forecasting of human BI. Past studies examined that simulations using the basic factors ATT, SN, PBC were able to predict around 40 % of the variation in BI (Koshta et al., 2022). Yet other studies on pro-environmental behaviour indicate that this level could be raised to 60 %, if the model is extended by integrating other context-related variables (Koshta et al., 2022; Sabbir et al., 2022). In line with this logic, we gathered insights from local public opinion surveys to amend the TPB with the factors awareness of consequences (AC), environmental concerns (EC) and policy concern (PRS).

4.2. Development of hypotheses

This study's modelling of hypotheses aimed to assess the predictability strength of the extended TPB. For this purpose, we first

investigate the relationship between AC and ATT as well as EC and ATT to assess the impact of both cognitive elements on repair attitude. In second instance, we investigated the model's single factor (i.e., AC, EC, PRS, ATT, SN, and PBC) impact's on BI to assess what constitutes the major driver behind repair intention. The resulting, TPB factor dependent hypotheses are outlined below.

4.3. Awareness of consequences (AC)

Awareness of consequences (AC) is defined as a cognitive or instrumental mechanism in an individual (Koshta et al., 2022). Incorporating AC into the TPB is considered as key for the explanation of behavioural intention: Wang et al. (2016) highlighted that AC is based on the end user's knowledge or comprehension of consequences derived from behaviour. Culiberg and Bajde (2013) and Kochan et al. (2016) additionally confirmed a positive relationship between pro-environmental recycling intention due to the awareness of consequences. Against these findings' background, we assume that AC exerts a positive effect on individuals' ATT towards a particular BI. Accordingly, we developed two hypotheses for AC:

H1a: Awareness of consequences positively and significantly influences attitude.

H1b: Awareness of consequences positively and significantly influences behavioural intention.

4.3.1. Environmental concerns (EC)

One of the key determinants of pro-environmental behaviour are environmental concerns that emerge from the general environmental disposition of end-users (Nguyen et al., 2016). Confirmed that EC is one of the most reliable indicators of people's pro-environmental intention and behaviour and often incorporated in TPB models to improve the prediction of behaviour. Previous literatures (Dwivedy and Mittal, 2013; Kumar, 2019; Nnorom et al., 2009) for example verify that a BI for recycling features a positive correlation with EC. Likewise, Dwivedy and Mittal (2013) report a positive relationship between EC and BI for recycling e-waste. Ibrahim et al. (2021) have shown that people who have a higher level of EC tend to have stronger positive attitudes towards pro-environmental behaviours such as green purchasing, waste sorting, and anti-littering. Given these findings, we set the following hypotheses:

H2a: Environmental concerns positively and significantly influence attitude.

H2b: Environmental concerns positively and significantly influence behavioural intention.

4.3.2. Policy concerns (PRS)

Based on Hong Kong's implementation of the producer responsibility scheme for WEEE (WPRS) in 2018. Dhanorkar and Muthulingam (2020) suggest that e-waste legislation may have altered individuals' behaviours by raising awareness about electronic repair or reuse, thus extending the life of existing products. Since there is no previous literature to test the relationship between PRS and repair behaviour, we assume a general awareness among local consumers about WPRS and that it shapes their behaviour to engage in repair. We therefore hypothesise that:

H3: Policy concerns positively and significantly influence behavioural intention.

4.3.3. Attitude towards repair practices (ATT)

Attitude refers to the user's evaluation of behaviour, which can be positive or negative (Ajzen, 1985). As a psychological inclination, attitude expresses a preference or non-preferred evaluation of a certain issue (Aboelmaged, 2021). Positive attitude is more common when the anticipated behavioural result is favourable, and vice versa. (Dhir et al., 2021). Dixit and Badgaiyan (2016) stated that when an action has a greater positive impact, the likelihood for people to develop a strong intent to perform a certain behaviour increases. Since attitudes can withstand the risks and uncertainties that come with making a decision, they have also been shown to be excellent indicators of pro-environmental behaviour (Liu et al., 2018). As prior research has reported some empirical support on the correlation between attitudes on pro-environmental intentions, the next hypothesis is phrased as:

H4: Attitude positively and significantly influences behavioural intention

4.3.4. Perceived behavioural control (PBC)

Perceived behavioural control (PBC) refers to the end user's perceived degree of difficulty or ease to perform a particular behaviour (Koshta et al., 2022). The end user's experience, perceived barriers, and expected results are among the PBC components (Ajzen, 1985; Shi et al., 2017). Ajzen (1985) elaborated that the PBC level affects the association between intention and behaviour. When the user has less control over their action then a weaker correlation happens between intention and behaviour. Russell et al., (2017) have indicated that perceived behavioural control positively effects intention to improve a pro-environmental behaviour in recycling. In the context of low-income countries, Researchers found that consumers' intentions to reuse or repair obsolete electronic devices, as well as their intention to recycle weekly at home, are both well predicted by behavioural control (Kianpour et al., 2017). On this basis we hypothesised that:

H5: Perceived behavioural control positively and significantly influences behavioural intention

4.3.5. Subjective norms (SN)

Subjective norms refer to the social pressure influencing users to engage in or disengage from a behaviour. It is derived from the beliefs of family members, friends, and colleagues (Ajzen, 1985) and reflects a person's recipience of social pressure to practice or abstain from a particular behaviour (Ajzen, 1991). According to Venkatesh and Davis (2000), a strong indicator of a person's intention to accept a new system is whether or not they are willing to live up to the standards of a reference group. It has also been seen that people, even if they have negative attitudes toward an innovation or system, adopt it because of social pressure. Specifically, Swinerd and McNaught (2015) outlined how subjective norms are a significant predictor of adoption in the early stages of new systems or innovations. Hence, we propose the following hypothesis:

H6: Subjective Norms positively and significantly influence behavioural intention

4.3.6. Behavioural intention (BI)

Behavioural intention (BI) describes a person's inclination to perform a given action (Ajzen, 2002). Given that the TPB explains intention as a precursor to behaviour, BI is taken as a factor influencing reuse, repair and recycling practices. For the context of Hong Kong, Wan et al. (2012) found that attitude, subjective norms, perceived behavioural control, awareness of consequences, the moral norms, and convenience significantly effects the behavioural intention to recycle. For the application to Hong Kong's circular engagement with electronics, BI is in this study defined as a person's desire or intention to repair electronic equipment in supports of the circular economy. In combination with the other components outlined here, the BI constitutes the final element for the study's TPB framework with its interlinked relationships (see Fig. 1).

4.4. Data collection and statistical analysis

Two surveys were designed by the authors to obtain information on EEE disposal patterns and to develop TPB model. Both surveys were conducted through the HKPORI platform by use of a questionnaire in both English and Traditional Chinese from February 2023 to May 2023. We applied a quantitative cross-sectional research approach by using a survey questionnaire with statements adapted from previous studies (see

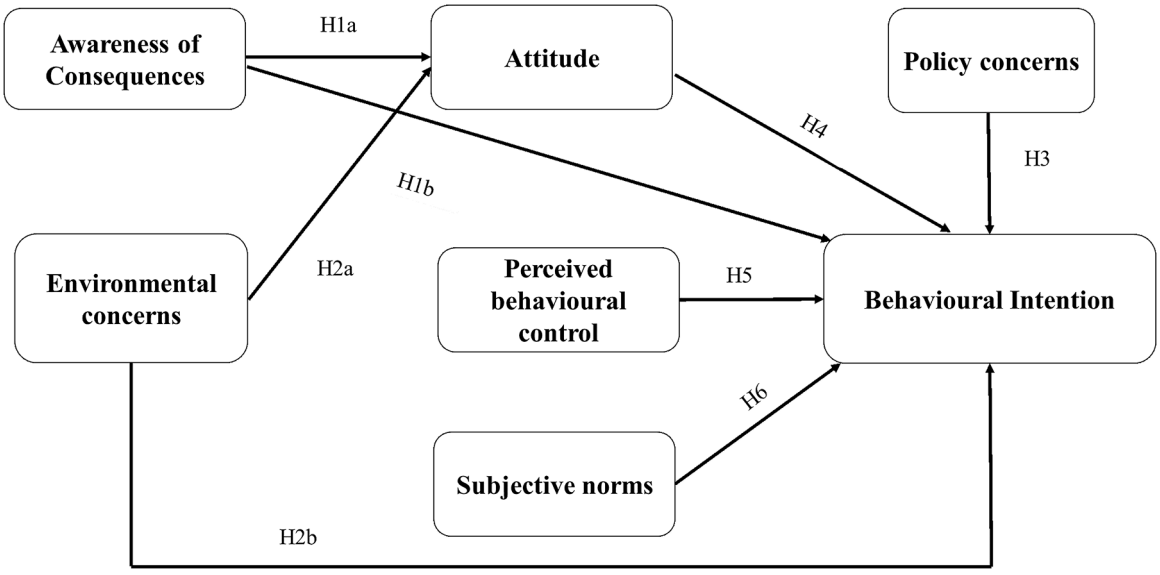

Fig. 1. Proposed Theory of planned behaviour (TPB) model with hypotheses.

supplementary data).

The first survey (n = 794) regarding consumer disposal patterns covered ten types of EEE officially designated for the Hong Kong WPRS, i.e. air-conditioner, refrigerator, washing machine, television, computer, laptop, printer, scanner, mobile phone and tablet. A questionnaire collected information from households regarding usage, lifecycle extension and disposal patterns of electronics. The survey achieved a total valid sample size of 794 households with a response rate of 79.4 % (see supplementary data, Table S1). Male and female showed close to equal distribution of (48.2 %) and (51.3 %) respectively. In age, 63.2 % percent of the participants were within the age range of 20–49 and 36.3 % within 50–60. Most of the participants were university level (45.5 %), employment status (70 %) and 30,000 – 49,999 income range (28.2 %). The descriptive statistics of frequency analysis have been analysed by applying IBM SPSS V. 23.

To apply the TPB model, a consumer repair survey was commissioned via a closed-type questionnaire format along a 5-point Likert scale (‘*strongly disagree*’, ‘*disagree*’, ‘*neither agree nor disagree*’, ‘*agree*’ and ‘*strongly agree*’). This research employed SPSS V.23 and Amos V.22 (IBM) for data analysis, facilitating a systematic examination of the findings. We first conducted an exploratory factor analysis using the principal component analysis method to evaluate the loading of variables. We estimated the reliability (or the internal consistency) of responses at the construct level, using Cronbach’s alpha (α). Then, we performed a descriptive analysis of the collected data for all individual Likert items to compare the means of responses. With the exploratory factor analysis results, we also executed confirmatory factor analysis and structural equation modelling (SEM) through the SPSS Amos software to create measurement and structural models. The SEM results were used to validate the research hypotheses by analysing the relationships between observed constructs and dependent constructs without measurement errors (Nachtigall et al., 2003). The second survey was achieved with total sample size of 609 (60.9 %) out of 1,000 disseminated questionnaire samples (see supplementary data, Table S1). The distribution of respondents was similar to the first disposal pattern survey (n = 794), in which male (50.9 %) and female (49.1 %) respondents featured near equal representation. Age range of 30-49 participated at 52.38 % while 49.3 % at university level, 77 % employment and 26.3 % at 30,000 – 49, 999 income range.

5. Results

5.1. Descriptive statistical analysis of EEE discarding by Hong Kong consumers

Table 1 shows that 52 % of respondents prefer to sell or give electronics to recyclers for further processing followed by 28 % seeking repair services. Yet, 18 % of respondents still discard electronics as general waste despite the implementation of the WPRS. In regard to repair routines for different electronic categories, Table 1 reveals a strong preference for repair options applied to high value-per-weight electronics, i.e. laptops (42 %), computers (38 %), tablets (37 %) and mobile phones (31 %) vis-à-vis more traditional white and brown goods.

5.2. Statistical analysis of EEE repair behaviour by Hong Kong residents

5.2.1. Exploratory factor analysis, descriptive statistics and Shapiro-Wilk test results

An exploratory factor analysis (EFA) was used to validate the observed variables for respective factors in the proposed research model (see Table S2). Here we followed Hair et al. (2010) in setting the indicator leading coefficient of a minimum threshold of 0.5 resulting in nine out of 30 questions being removed due to a factor loading threshold of less than 0.5. In the factor reliability analysis results, Cronbach’s Alpha values of all constructs were ranged within a minimum of 0.710 a maximum of 0.898, with all values surpassing the acceptable threshold of 0.5. As a result, all TPB components inquired through the questionnaire items were suitable for further examination. The descriptive statistical analysis performed with SPSS indicated all standard deviation values within ±2 (Table S3). The subsequent Shapiro-Wilk test revealed a significant deviation from normality, so median values are used to describe the data points.

The findings indicate that Hong Kong consumers clearly perceive electronic devices as valuable products (AC1 = 4/5), while acknowledging that these include toxic substances and feature a potentially harmful impact of the environment (AC2 = 4/5). Consumers strongly agreed on waste separation being the correct way of handling end-of-life (EOL) electronics (AC3 = 5/5) and that CE practices are good for the environment (AC4 = 4/5). Secondly, they showed high levels of care for their surrounding environment (EC1 = 4/5 and EC2 = 4/5) and willingness to pay for sustainable products (EC3 = 4/5). Thirdly, interviewees stated a notable influenced from the WPRS when disposing

Table 1
Consumer disposal pattern of EEE (N = 794).

Disposal decision	AC	Fridge	WM	TV	PC	Laptop	Phone	Tab	PRN	Scan	Mean
Discarded as general waste	5 %	8 %	7 %	14 %	22 %	18 %	22 %	21 %	30 %	27 %	**18 %**
Sold/Gave to recycler	69 %	67 %	67 %	65 %	38 %	37 %	37 %	37 %	48 %	55 %	**52 %**
Tried to have them repaired	**26 %**	**26 %**	**26 %**	**20 %**	**38 %**	**42 %**	**31 %**	**37 %**	**20 %**	**16 %**	**28 %**
Other responses	1 %	0 %	0 %	1 %	2 %	3 %	9 %	5 %	2 %	2 %	**2 %**

Abbreviations: AC, air conditioner; Fridge, refrigerator; WM, washing machine; TV, television; PC, computer; Phone, mobile phone; Tab, tablet; PRN, printer; Scan, scanner.

electronic waste (PRS1 = 4/5; PRS2 = 4/5 and PRS3 = 4/5) and exhibit a strong preference for repair over recycling (ATT1 = 4/5, ATT2 = 4/5 and ATT3 = 4/5). Hong Kong consumers stated that they have time to bring devices to repair shops (PBC1 = 4/5) and also express considerable disagreement regarding their ability to repair electronic themselves (PBC4 = 2/5) or find access to repair systems easily (PBC3 = 3/5). Regarding subjective norms, respondents neither significantly agree nor disagree with following friends or neighbours should they start engaging

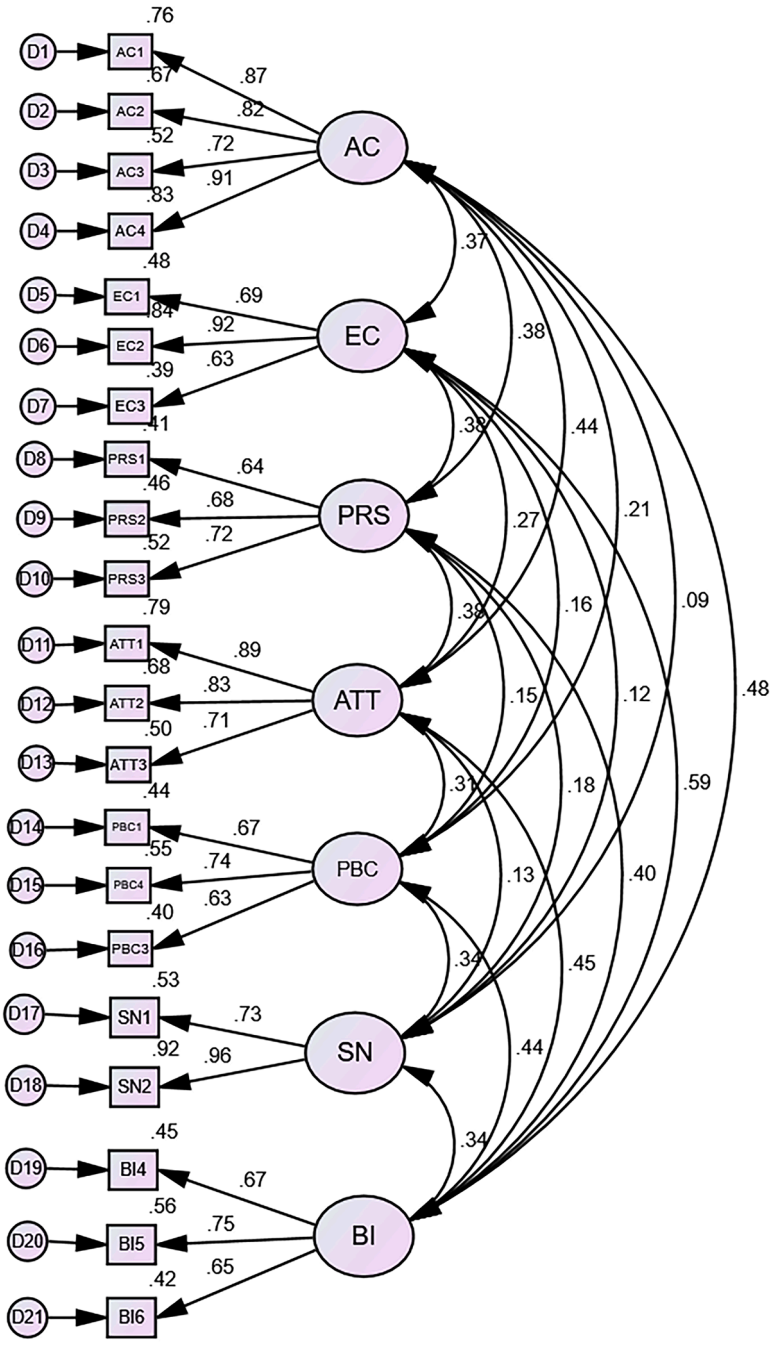

Fig. 2. Measurement model for proposed TPB model.

in electronics repair (SN1 = 3/5 and SN2 = 3/5). In final instance, interviewees exhibited a higher intention to repair and dispose EOL electronics in an environmentally friendly manner, as well as being interested in knowing more about the CE (BI4 = 4/5, BI5 = 4/5 and BI6 = 4/5).

5.2.2. Confirmatory factor analysis

After identifying the factor structure from EFA, confirmatory factor analysis (CFA) is used to test whether the data fits the hypothesized factor structure derived from the EFA. As part of the confirmatory factor analysis (CFA), the AMOS software was used to examine convergent validity and discriminant validity according to the suggestion of Fornell and Larcker (1981) (see Fig. 2). The resulting standard regression weights from the measurement were then taken to compute average variance extracted (AVE) and the composite reliability (CR). AVE is a measure of convergent validity, which assesses the degree to which a latent construct explains the variance of its indicators or observed variables while CR is a measure of internal consistency or reliability, similar to Cronbach's alpha (Fornell and Larcker, 1981).

The AVE and CR values, rank above 0.50 and 0.70, respectively, and thus constitute an adequate convergent validity and construct reliability, as stipulated by Fornell and Larcker (1981). For the cluster variables 'PC, 'PBC' and 'BI', for which the AVE value is below 0.5, the results are still acceptable. For such cases, stated that the convergent validity of the construct is acceptable if the composite reliability is higher than 0.7. Overall, the analysis result for the AVE ranged from 0.462 to 0.726, and CR ranged from 0.72 to 0.9, above the recommended cutoff point of 0.7 (Table 2). Therefore, the AVE and CR results can be assumed that convergent validity is established. Additionally, discriminant validity and value of model fit indices have been tested (Table S4 and S5), which confirmed the conformity of values and model fitness. According to the analysis result of model fit indices from both measurement and structural models (see Table S5), the hypothesised model exhibits a very good fit for the collected data.

5.2.3. The result of hypotheses testing

SEM was calculated using AMOS software and estimated using maximum likelihood (ML) estimation. Analysis results are presented in Table 3: Standardized coefficient (β) represents the amount of change in the dependent variable that is attributable to a single standard deviation increase in the predictor variable (Menard, 2004); T-values indicate whether path coefficients are statistically significant and can be interpreted based on the chosen significance level (e.g. 1.96 for $p<0.05$); The squared multiple correlations (R^2) measure how the exogenous variables describe or predict the endogenous variables. It measures the inner model predictive accuracy by stating the model percentage of construct variance (Hair et al., 2021). Although there is no generally acceptable level of R^2 value, $R^2 < 0.2$ is considered as the low predictive power of the model, $0.2 <= R^2 < 0.5$ moderate predictive power and $0.5 \leq R2$ is the high predictive power of the model (Sanchez, 2013).

According to the SEM results shown in Table 3 and Fig. 3, awareness of consequences (β = 0.388, t = 7.859) and environmental concern (β = 0.137, t = 2.891) positively and significantly influence the attitude towards repair, which means that H1a and H2a were supported. Further, awareness of consequences (β = 0.195, t = 3.896), environmental concerns (β = 0.473, t = 8.632), attitudes (β = 0.164, t = 3.335), perceived behavioural control (β = 0.224, t = 4.282) and subjective norms (β = 0.175, t = 3.578) exhibit a positive and significant influence on behavioural intention to repair while only WEE policy concern (β = 0.068, t = 0.134) was not statistically significant to drive repair behaviour. Therefore, H1b, H2b, H4, H5 and H6 were supported while H3 were not supported. Environmental concern showed the strongest influence on repair behaviour followed by perceived behavioural control, awareness of consequences, subjective norms and attitudes. The results find that R^2 value for attitude (ATT) is 0.21 (21 %) and for repair behavioural intention (BI) is 0.54 (54 %), denoting moderate predictive power for ATT and high predictive power of BI. The prior TPB papers generally explained the lower and moderate predictive power of behavioural intention and present study indicated that extending TPB New model by AC, EC and PRS gained higher predictive power for the proposed TPB model.

Table 2
The analysis results of AVE and CR.

Latent Variable	Retained Manifest	Std. Regression Weights	AVE	CR
Awareness of consequence (AC)	AC1	0.873	**0.695**	**0.901**
	AC2	0.82		
	AC3	0.718		
	AC4	0.912		
Environmental concern (EC)	EC1	0.692	**0.57**	**0.795**
	EC2	0.916		
	EC3	0.626		
WEEE Policy Concerns (PRS)	PRS1	0.641	**0.466**	**0.723**
	PRS2	0.682		
	PRS3	0.722		
Attitude (ATT)	ATT1	0.889	**0.658**	**0.851**
	ATT2	0.827		
	ATT3	0.707		
Perceived behavioural control (PBC)	PBC1	0.666	**0.462**	**0.720**
	PBC2	0.629		
	PBC3	0.74		
Subjective Norms (SN)	SN1	0.73	**0.726**	**0.839**
	SN2	0.959		
Behavioural Intention (BI)	BI1	0.673	**0.479**	**0.737**
	BI2	0.751		
	BI3	0.647		

6. Discussion

For any study on EOL electronics management, consumer patterns and governmental regulations are considered key influencing factors. For the case of Hong Kong, however, the absence of regulation, have left consumer preferences to be shaped by market, habituation and civil values. Our descriptive analysis shows that 52 % of respondents preferred recycling EOL electronics, followed by 28 % opting to repair and 18 % somewhat carelessly discard electronics as general waste. Yet instead of ending up in landfills, informal collectors or cleaning personal at housing estates often extract devices from the general waste stream and resell these to stakeholders engaging in repair and refurbishment. A partial explanation for repair ranking relatively low might be that consumers may not always be aware of the defect that causes product failure (Bovea et al., 2017). In parts however, that pattern might have also arisen from a lack of local repair policy and supportive financial mechanisms. An indication regarding the importance of the latter is that Hong Kong consumers primarily tend to repair high value-per-weight appliances. It suggests that economic considerations play a significant driver in their decision.

Policy elements on the other hand are not substantially relevant to repair practices. That is not to say that Hong Kongs WPRS does not have an impact on circularity for EOL device management. Given that recycling enjoys strong preference among residents, it merely implies that policy is as of now not promoting higher levels of circulating among EEE management such as repair. Specifically, policy concern (H3), was found not to significantly influence to repair behaviour. This should be subject of substantial overhauls in local legislation. As previous literature, Dhanorkar and Muthulingam (2020) has shown, e-waste legislation can alter individuals' behaviour towards repair or reuse if it manages to raise awareness. In that regard, we find by testing for H4 that there is a strong association between attitude and behavioural intention for EEE repair.

Table 3
Proposed TPB model with hypotheses results.

Hypotheses	Structural Path	Std. Coefficient (β)	p-values	t-values	R^2	Results
H1a	AC >> ATT	0.388	***	7.859	**0.21**	Supported
H1b	EC >> ATT	0.137	.004**	2.891		Supported
H2a	AC >> BI	0.195	***	3.896	**0.54**	Supported
H2b	EC >> BI	0.473	***	8.632		Supported
H3	PRS >> BI	0.068	.134	1.497		Not supported
H4	ATT >> BI	0.164	***	3.335		Supported
H5	PBC >> BI	0.224	***	4.282		Supported
H6	SN >> BI	0.175	***	3.578		Supported

Note. * * means p < 0.01, *** means p < 0.001. t-values > 2 means significant.

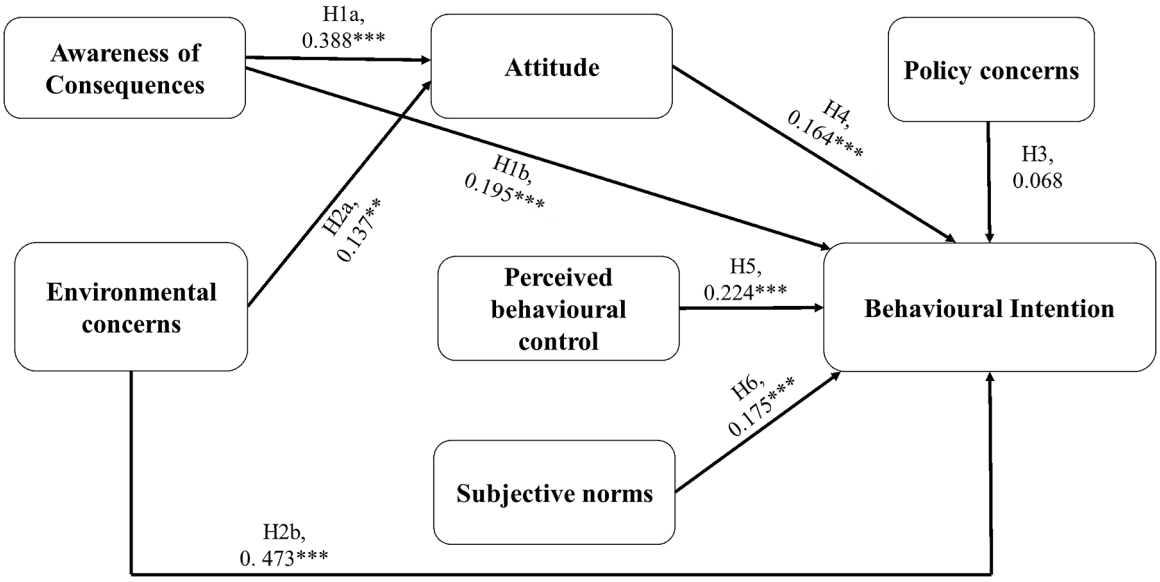

Fig. 3. Results of the proposed TPB model with hypotheses.

The implication is that people can have a strong intent to perform repair activities, if they believe that repair is better than recycling for the context of the CE. The task to inform and raise awareness in turn liaise with legislators and policy-makers.

Moreover, we find that nearly all the hypotheses are supported, with a notable result being that the strongest influence on behavioural intention for repair came from environmental concern, followed by perceived behavioural control, awareness of consequences, subjective norms and attitudes. Kianpur et al. (2017) stated that the intention to return EOL products is influenced by consumers' attitudes and perceived behavioural control, highlighting the importance of these factors in reverse supply chain management. Additionally, Parajuly et al. (2023) revealed that personal values, beliefs, and attitudes are the main drivers of the intention to repair e-products, while the ability to repair significantly influences this behaviour. Our investigation's finding is in line with these results and moreover features similarities to Mak et al. (2018): Their work on Hong Kong indicated that ATT and PBC were positively linked to BI for managing plastic waste, while SN was similar to our case exhibiting a non-significant impact. One possible explanation is that people featuring an awareness of environmental impacts and CE practices hold stronger attitudes towards and are more prone to repair EEE.

Similarly, EC (H2a and H2b) significantly influences BI – be that either directly or indirectly via shaping ATT. This finding is in line with previous studies Bakır (2023) and Yanyan et al. (2023), who assert that EC is a critical determinant of consumers' BI to purchase green products. Newton et al. (2015) also stated that EC has both direct and indirect effects on environmental purchase intentions, which further highlights the importance of integrating the factor into the TPB framework. The reason for this finding could be that Hong Kong consumers take substantial consideration of environmental issues, which is often conceptualised as an immediate antecedent to environmental purchase intentions (Paladino and Ng, 2013). The TPB suggests that attitudes towards green products, influenced by green consciousness and body image awareness, can lead to purchasing intentions. These attitudes are often influenced by the desire to maintain a favourable social reputation (Kaur and Gupta, 2022). Therefore, it can be assumed that Hong Kong people are prepared to purchase products and services from firms with a reputation for being environmentally friendly. Hence, the results reveal that respondents, who concerned the environmental issues and environmentally friendly consumption, might be more ready to adopt sustainable practices such as EEE repair.

7. Implications

7.1. Theorical implications

This study provides three main theoretical implications of the literature. Firstly, as this is the first empirical study to use the TPB framework to examine the drivers of consumers' desire to repair EEE in a circular economy. Moreover, the study incorporated three extended factors, environmental concern, awareness of consequences and policy concerns in the TPB framework to improve its explanatory power. The present study's findings support the effectiveness of the TPB framework in understanding repair behavioural intention to promote a circular economy. Another contribution of this study is to extend literature on the CE concept. To the best of our knowledge, very limited attempts have been made to understand consumer's CE behaviour to repair EEE.

In contrast to prior research, this paper examined repair intention as belonging to higher ranked R-strategies of the EC, which is influenced by the factors of awareness of concern for CE and attitude towards CE. As far as the implications are concerned, this study broadens the understanding of the implications of circular economy behaviours, given that researchers till now have paid attention mainly to recycling. Finally, the study findings offer crucial insights into the determinants of Hong Kong EEE users' intention towards repairing EEE. AS exemplified in the local key policy, the WPRS, Hong Kong policymakers mainly focus on recycling instead of repairing in the first place. Thus, a limited understanding on the Hong Kong consumer's intention to repair EEE still exits. The results are pertinent and ought to encourage researchers to delve deeper into the notion of circular economy in various cultural contexts.

7.2. Policy implications

The current study offers insights for policy- and decision-makers regarding end users' repair behaviour of electronics. First, the positive association of (a) awareness of consequences and (b) environmental concern with behavioural intention to repair indicates potential angles for shaping local residents' EEE repair behaviour. Hence, to further encourage individuals to engage in repair activities, policymakers should put more emphasis on events and campaigns to raise public awareness on the negative environmental impacts of WEEE generation. Given the positive relationships identified in the study, doing so are likely to positively impact the behavioural intention for EEE repair in Hong Kong. Second to that, we found that subjective norms among Hong Kong residents are positively associated with behavioural intention. Yet, nearly 65 % of respondents were neutral regarding social norms' influence on individual repair behaviour. By implication, any policy efforts to strengthen the effect of subjective norms on decision-making would likely entail relatively high (administrative) costs and result in relatively limited improvements in strengthening repair behaviour.

A third result is the positive association of perceived behavioural control with behavioural intention to repair. However, over 60 % of respondents indicated that they would not know how to repair EEE, while less than 20 % claimed to have sufficient knowledge to repair EOL EEE. For policy this would imply to foster the development of DIY repair platforms: This could mean to promote online formats such as planned by the EU via it's right to repair regulation or by means of fiscally fostering the emergence of DIY repair cafés. These systems have been identified as highly useful given their potential to provide free repair education and generate positive repair experiences through vicarious learning (Lundberg et al., 2024; Madon, 2022). In final instance, our findings have implications for the regulatory framework design. On the one hand our findings have shown the Hong Kong's current WPRS policy does not have any beneficial relationship on individuals' repair behaviour. This is most likely due to the regulations' focus on promoting recycling and its inadvertent impediment for the, in the sense of the CE, more desirable practices of reuse, repair, refurbishment, and remanufacture. On the other hand, this does not imply that there is no room for policy influence on individual consumer behaviour. The findings underscore the notable impact of perceived behavioural control and environmental concerns on behavioural intention to repair, which in turn provide legal room for measures that appeal to these factors. One option are subsidy measures that support electronics repair, for which Hong Kong policymakers could take the Austrian Repair Bonus for EEE (Lechner et al., 2021) as a basis. As a mechanism, this could strengthen perceived behavioural control and facilitate repair behaviour. In terms of policy familiarity for local administrators, earlier research has shown that subsidies are commonly used for circular management of waste-paper (Chen and Steuer, 2024) and plastic bottles (Steuer and Chen, 2023) in Hong Kong. Another policy option appealing to consumers' awareness of consequences and environmental concerns could be mandatory labelling schemes in the sense of France's repairability and durability indices. This could constitute an intermediate step towards the development of a right to repair framework in the city, which would not only set quality and safety standards, but could also provide an attractive angle to nudge informal EEE repair stakeholders to participate.

8. Conclusion

EEE is a major, yet little analysed waste stream in Hong Kong. Electronic product repair can reduce the WEEE generation by lengthening their lifetimes in the circular economy, but no prior research has examined how relevant psychological factors shape consumers' behaviour on EEE repair in Hong Kong. To address this gap, this study conducted an online survey among 609 Hong Kong residents, which showed that 28 % of respondents attempted to find repair services. The respondents exhibited a strong preference for repair options applied to high value-per-weight electronics, i.e. laptops, computers, tablets and mobile phones. To strengthen the analytical depth, we employed an extended TPB model, which included an assessment on factor influence for awareness of consequences, environmental concerns, and policy concerns on behavioural intention to repair EEE. The TPB model features a relatively strong predictive power for behavioural intention ($R^2 = 0.54$). The results show that environmental concern (H2b: $\beta = 0.473^{***}$, $t = 8.632$) showed the strongest influence on the behavioural intention to repair, followed by perceived behavioural control (H5: $\beta = 0.224^{***}$, $t = 4.282$). On the other hand, policy concern (H3: $\beta = 0.068$ ns, $t = 0.134$) was not statistically significant. Drawing on these findings, we propose that policymakers should develop a set of voluntary, market-based and regulatory measures to strengthen these influence factors behind behavioural intention for repair. These include measures that strengthen the awareness on environmental consequences (e.g. campaigns on the environmental impact arising from WEEE); subsidy mechanisms to support EEE repair infrastructure (e.g. DIY repair cafés) thereby enhancing perceived behavioural control; and mandatory labelling (e.g. repairability/ durability indices) to increase the impact of regulatory policy on EEE design and purchasing behaviour.

9. Limitations of the study

There are some limitations that the study was unable to address, but which bears relevance for future research. First, beyond the investigated factors there are other aspects that influence consumer's intention to repair, such as original purchasing price and size of EEE (Parajuly et al., 2023; van den Berge et al., 2022). The relevant rationale is that consumers attribute a higher intrinsic value to expensive products even if they become outdated. Future work could thus explore whether the repair or recycling behaviour depends on price or size related characteristics of EEE. In regard to social norms, Hong Kong people expressed indifference to peer pressure from friends and neighbours. Yet, they strongly agree to social media wielding a degree of influence. Due to the limitation of the questionnaire length, we decided to drop the question for social media influence on repair practices. Future work should therefore treat social norm and social media use as two separate variables of influence on Hong Kong consumers' EEE repair behaviour. Finally, it must be noted that the TPB can in its treatment not go beyond the exploration of behavioural intentions. By implication, the survey findings and the TPB model merely capture and analytically process what people claim to do, instead of how they actually behave in real-life contexts (Chernozub, 2022; Hsu and Huang, 2010). Follow-up research could address this limitation by engaging in field research using (non-) participant (direct) observation to gather first-hand evidence at points of WEEE disposal and on transfers to collectors and/ or repair shops.

CRediT authorship contribution statement

Soe Oo May: Writing – review & editing, Writing – original draft, Visualization, Validation, Software, Resources, Methodology,

Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Benjamin Steuer:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization.

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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In regard to involved human subjects, the research has undergone ethical evaluation and received approval by the Human and Artefacts Research Ethics Committee (HAREC) of the Hong Kong University of Science and Technology (Human Research Ethics Protocol HREP-2024-0124.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.resconrec.2024.108036.

Data availability

Data will be made available on request.

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