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Leveraging Mobile Distribution Platforms to Drive E-Waste Recycling Satisfaction of Gen Z in Malaysia*

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Abstract

Purpose: Malaysia is grappling with a significant e-waste management challenge due to rapid population growth. Surprisingly, e-waste volumes expected to rise from 12,344 thousand units in 2016 to 24,504 thousand units by 2025. Low public engagement in recycling initiatives is a key issue, compounded by mobile distribution platforms with performance issues such as slow loading times, glitches, and unintuitive designs. Due to that, this study applies an extended E-SERVQUAL framework to assess the impact of mobile distribution platform features on e-waste recycling intentions and user satisfaction. **Research design, data and methodology:** A quantitative survey of 200 urban Generation Z individuals, aged 20 to 28, experienced in using recycling apps, was conducted and analysed using PLS-SEM. **Results:** The findings indicate that Privacy, System Availability, Fulfillment, and Green Knowledge significantly enhance User Satisfaction, while Efficiency has no direct impact. Indirectly, only Fulfillment through Green Knowledge positively influences User Satisfaction, with no significant effects observed for Privacy, System Availability, or Efficiency. **Conclusions:** This research highlights the importance of enhancing convenience via features such as easy access to recycling locations, scheduling pickups, and sending recycling reminders can increase participation. These insights provide practical recommendations for improving mobile distribution platforms to boost public engagement in e-waste recycling and foster sustainable behaviour.

Keywords : E-Waste Recycling, Mobile Distribution Platforms, Generation Z, E-SERVQUAL, User Satisfaction

JEL Classification Code : M30, M31, Q2, O31

1. Introduction

The generation of e-waste is increasing at a rate that surpasses global population growth. Surprisingly, its production has risen threefold compared to population expansion (Andeobu, 2021). In 2016, the global average e-

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waste generation reached 6.1 kg per capita, representing an increase from 5.8 kg in 2014. This figure is projected to rise further to 6.8 kg by 2021. Similarly, Malaysia's growing population has led to a significant increase in e-waste generation. The total volume of electronic waste in Malaysia is anticipated to experience significant growth from 12,344 thousand units in 2016 to an estimated 24,504 thousand units by 2025, nearly doubling over a decade (DOE, 2022). Television and mobile phones are major contributors to the increase in e-waste. The annual volume is expected to reach 10 million tons, with a growth rate of 14% per year (Shumon et al., 2014).

A key challenge in managing e-waste in Malaysia lies in its collection, distribution, and recycling logistics. The inefficiencies in the e-waste supply chain from sourcing and transporting recyclable materials to processing and final disposal. Despite the availability of mobile distribution platforms designed to facilitate recycling, these tools face criticism for technical shortcomings such as slow loading times, glitches, and unintuitive interfaces (Alalwan et al., 2020). These issues hinder their effectiveness in streamlining the distribution of e-waste collection and recycling activities, limiting their role in fostering recycling behaviour (Pang, 2025). As a result, only 25% of e-waste is recycled in Malaysia, leaving a significant portion improperly handled. The financial value of mismanaged e-waste is estimated at MYR 3 billion, reflecting missed opportunities for businesses engaged in the e-waste trade (DOE, 2022).

Recent technological advancements offer promising solutions for optimizing e-waste logistics (Saeliw et al., 2019). These innovations also hold significant potential for improving recycling rates. Innovations such as smart devices with artificial intelligence and QR code sensors can assist in sorting and tracking recyclable materials, enhancing the efficiency of e-waste collection and trade operations (Yahya et al., 2020). In Malaysia, QR code-enabled e-waste collection services to streamline recycling processes and boost public participation. The DOE has partnered with private companies such as Maxis Bhd and ERTH to introduce initiatives like the MyEwaste smartphone application aimed at locating collection centers and raising awareness about recycling (Bernama, 2023). However, public engagement with these initiatives remains limited. This highlights the need to better understand consumer behaviour and improve the effectiveness of these platforms. (Iparraguirre-Villanueva et al., 2023).

To address the challenges of low public participation, this study uses an extended E-SERVQUAL framework Parasuraman et al. (2005). It evaluates how mobile distribution platforms influence intentions toward e-waste recycling and improve user satisfaction. This approach aims to identify the drivers behind e-waste recycling behaviours and develop strategies to boost consumer participation. By merging technological innovation with insights into consumer behaviour, this study aims to offer practical recommendations for improving e-waste management systems in Malaysia.

2. Literature Review

2.1. Mobile Applications for E-Waste Recycling

Malaysia faces significant challenges in managing e-waste due to the increasing volume of discarded electronics and improper disposal practices (Hashim et al., 2025). A mobile application can serve as a practical solution to address this issue by increasing access to recycling centres, and raising public awareness (Huenerfauth, 2014). The app could include features such as a locator for e-waste collection centers, allowing users to easily find the nearest certified facilities. However, challenges such as public adoption, infrastructure expansion and the costs of app development must be addressed to ensure success. By leveraging technology, this mobile application could support Malaysia's transition toward a circular economy and improve its e-waste management practices (Zainuddin et al., 2024).

2.2. Theoretical Background

The theory developed by (Parasuraman, 1985) advocated differences could be used to assess service quality. Parasuraman et al. (1988) suggested SERVQUAL as a metric for service quality that covered five dimensions for which the expectations gap should be measured: reliability, responsiveness, assurance, empathy, and tangibility. The growing of internet and mobile-based services led to the metric being subject to many modifications. Previous studies across various fields have utilized the e-SERVQUAL model to evaluate the quality of e-services (Joy et al., 2023). This adaptation considers the unique attributes of electronic services, such as website interactivity, usability, and security (Parasuraman et al., 2005). Given the growing importance of digital services in customer interactions, e-SERVQUAL provides a structured way to assess and improve these services (Zeithaml et al., 2002).

2.3. User Satisfaction

User satisfaction is considered one of the most essential areas within the marketing discipline (Jamal, 2004). It evaluates how effectively a product or service meets a customer's needs and expectations (Khan et al., 2022). Achieving user satisfaction is a crucial industrial objective

for all sectors, involving businesses, service and manufacturing (Hill & Alexander, 2017). User satisfaction can also be defined as a company's ability to meet clients' preferences which include psychological, emotional, and commercial needs (Hawkins & Hoon, 2019).

2.4. Privacy

According to Parasuraman et al. (2005) privacy emphasizes on websites or mobile applications that provide security and consumer information protection. Privacy within electronic services is a critical component because it concerns the protection of personal data and information (Hasal et al., 2021). Research shows that concerns about security and privacy significantly affect customer trust in e-payment platforms, thereby influencing their willingness to use these services (Poudel et al., 2023). New protocols using partially blind signatures and blockchain technology have been created to protect privacy by ensuring anonymous and untraceable transactions (Momeni, 2024). Based on these findings, the subsequent hypotheses are presented:

H1: There is a positive relationship between privacy with user satisfaction.

2.5. System Availability

Parasuraman et al. (2005) identified system availability as a critical dimension of the e-service quality framework, emphasizing its role in ensuring customer satisfaction and trust. System availability is closely connected to the technical functionality of online services and directly impacts customer evaluations (Robustin, 2023). System availability is crucial to facilitate the smooth implementation of sustainable practices and technologies, ensuring it aligns with customer expectations (Ighomereho et al., 2023). If customers experience frequent downtimes or errors, they may question the reliability of green initiatives, resulting in reduced usage and negative perceptions (Hermann et al., 2024). In light of the reviewed literature, this research develops the subsequent hypothesis:

H2: There is a positive relationship between system availability with user satisfaction

2.6. Efficiency

Efficiency as part of E-SERVQUAL demonstrates how consumers can navigate a website, search for products, and complete transactions Parasuraman et al. (2005). Numerous studies have established a positive correlation between efficiency and customer satisfaction. When users can easily access information and complete transactions without frustration, they are more likely to become a returning customer (Alalwan et al., 2020). Efficient systems reduce waste by optimizing processes and minimising energy consumption during transactions (Stevic et al., 2022). This aligns with broader sustainability goals by promoting responsible consumption. Grounded in the findings of previous studies, this research puts forth the ensuing hypothesis:

H3: There is a positive relationship between efficiency with user satisfaction

2.7. Fulfillment

Fulfillment refers to the accuracy and completeness of orders, including timely delivery and the reliability of service commitments. It encompasses factors such as whether the product received matches what was ordered, whether it arrives on time, and whether the service provider keeps its promises regarding availability and delivery (Parasuraman et al., 2005). Reliable fulfillment processes can serve as a competitive advantage, particularly in sectors where consumers have numerous options (Wulandari et al., 2024). This dimension is particularly relevant in sustainable services, where consumers increasingly expect not only quality but also ethical considerations in product sourcing and delivery (Lopes et al., 2024). The integration of these findings leads to the following hypotheses being posited:

H4: There is a positive relationship between fulfillment with user satisfaction

2.8. Moderating Effect of Green Knowledge

Users with higher green knowledge exhibit greater willingness to pay for environmentally friendly services. This shift reflects a broader societal trend toward green consumerism, where knowledge empowers individuals to make informed, sustainable choices (Ikhsan et al., 2024). Green marketing strategies that emphasise transparency and environmental impact have proven effective in retaining environmentally conscious customers (Desy et al., 2021). Zhang et al. (2024) found that integrating green service initiatives within e-commerce platforms leads to increased customer engagement and satisfaction. Based on these findings, the hypotheses outlined below are proposed:

H1a: Green knowledge moderates the relationship between privacy and user satisfaction.
H2a: Green knowledge moderates the relationship between system availability and user satisfaction.
H3a: Green knowledge moderates the relationship between efficiency and user satisfaction.

H4a: Green knowledge moderates the relationship between fulfillment and user satisfaction.

Figure 1 illustrates the research framework to test specific hypotheses before conducting the study.

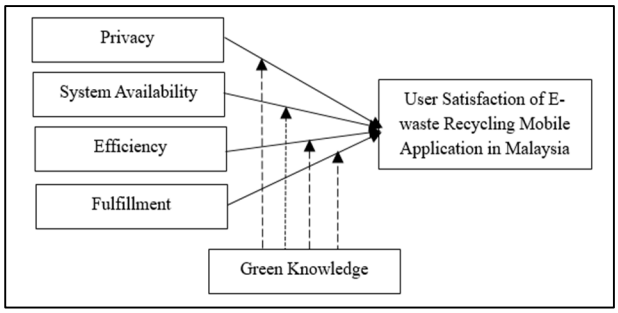

Figure 1: The Research Framework of This Study

3. Research Methodology

3.1. Population and Sample

To ensure relevant and meaningful data, this study employs purposive sampling. This method facilitates the deliberate selection of individuals who meet criteria and supports the research objectives (Campbell et al., 2020). By concentrating on the experience of participants, purposive sampling enhances the validity and the reliability of the findings (Kuppelwieser et al., 2019). This study employed G*Power to calculate the required sample size, a vital tool for ensuring adequately powered studies and achieving reliable statistical outcomes (Faul, 2009). Using G*Power, the minimum sample size necessary for a multiple regression analysis, with f^2=0.15, an alpha level of 0.05, a statistical power of 0.95 and 15 predictors was determined to be 200.

Reflecting to that, the study targets 200 Generation Z, specifically those from aged 20 to 28. Another criterion of respondents includes residing in urban areas and possessing prior experience with mobile applications for e-waste recycling. This demographic represents an ideal sample, as this generation characterised as digital natives with extensive exposure to technology (Prakash et al., 2024). Urban residency ensures access to advanced recycling infrastructure, which is often centralized in metropolitan regions. Furthermore, prior engagement with mobile applications for e-waste recycling guarantees participants can provide insights, thereby contributing to a robust understanding of the study's focal area (Ismail & Hanafiah, 2020).

3.2. Questionnaire Development

The questionnaire is divided into three main sections: Part A, B and C. Part A comprises five questions designed to assess the overall user satisfaction with mobile applications for e-waste recycling (Lee & Lin, 2005). Part B includes 25 questions focusing on e-SERVQUAL dimensions Parasuraman et al. (2005) and green knowledge Gleim et al. (2013), providing a detailed evaluation of service quality and environmental awareness. Lastly, Part C gathers demographic information about the respondents.

All questions are adapted from previous studies but have been modified to align with the objectives of this research. In total, the questionnaire comprises 30 items. All statements are evaluated using Likert scale, ranging from strongly disagree (1) to strongly agree (5), ensuring a standardized measurement of participants' perceptions and opinions.

3.3. Statistical Technique

Partial Least Squares Structural Equation Modeling (PLS-SEM) is a multivariate analysis method commonly used in social sciences and business. It is employed to model complex relationships between observed and latent variables, and its flexibility in handling such models makes it a popular choice for researchers (Hair et al., 2019). This method is widely used to explore theoretical frameworks and validate constructs across various settings (Sarstedt et al., 2021).

4. Result of Data Analysis

4.1. Demographic Profile

The demographic details of the survey respondents were examined using descriptive analysis and are categorised based on gender, ethnicity, age, and education level. Table 1 revealed that the majority of respondents were female (52.5%), while male respondents accounted for 47.5%. In terms of ethnicity, Malays comprised the largest proportion at 49%, followed by Chinese (28%), Indian (16%), and others (7%). The age distribution indicated that the largest group of respondents was aged 26–28 years (41.5%), followed by those aged 23–25 years (32%) and 20–22 years (26.5%). Regarding education level, the descriptive analysis showed that 46% of respondents held a bachelor's degree, 36.5% had a Diploma, 10% possessed a Master's degree, 2.5% held a PhD, and 5% reported other educational qualifications. This analysis highlights the diverse characteristics of the sample.

Table 1: Fitness of Measurement Model

Details	Demographic Variable	Frequency	Percentage (%)
Gender	Male	95	47.5
	Female	105	52.5
Ethnicity	Malay	98	49
	Chinese	56	28
	India	32	16
	Others	14	7
Age	20-22 Years old	53	26.5
	23-25 Years old	64	32
	26-28 Years old	83	41.5
Education Level	Diploma	73	36.5
	Bachelor's Degree	92	46
	Master's Degree	20	10
	PhD	5	2.5
	Others	10	5

4.2 Measurement Model

The table displays the assessment of the measurement model in Partial Least Squares Structural Equation Modeling (PLS-SEM), which includes constructs, factor loadings, Average Variance Extracted (AVE), Composite Reliability (CR), and Cronbach's Alpha (CA). This analysis confirms the reliability and validity of the constructs utilized in the study. The constructs analyzed in this model consist of Privacy, System Availability, Efficiency, Fulfillment, Green Knowledge, and User Satisfaction.

Each construct in Table 2 represented by multiple items aimed at measuring it effectively. However, items with low factor loadings (less than 0.50) have been excluded to enhance both construct validity and reliability. The AVE metric evaluates the convergent validity of the constructs, ensuring that the items within each construct account for a significant portion of the variance. An AVE threshold of 0.50 or higher signifies adequate convergent validity (Fornell & Larcker, 1981). All constructs in this study satisfy this criterion, portraying AVE values between 0.653 (Green Knowledge) to 0.863 (Fulfillment), indicating that the retained items effectively represent the intended constructs. Additionally, factor loadings demonstrate the strength of the relationship between each item and its respective construct. A loading above 0.7 is generally considered acceptable for convergent validity. In this study, Items with low loadings were removed to improve the model's quality including Privacy: PRI2 and PRI3 (low loadings of 0.245 and 0.247); System Availability: SYS4 (loading = 0.113); Efficiency: EFF2 (loading = 0.326); Fulfillment: FUL4 (loading = 0.398) was deleted. After the removal, all constructs exhibit CR values exceeding 0.90, demonstrating excellent reliability.

Similarly, all constructs show CA values greater than 0.80, providing further confirmation of the reliability of the measurement scales. This model underscores the robustness of the measurement scales and establishes a solid basis for structural model analysis. Future research utilising this measurement model can confidently interpret the relationships among constructs in e-waste recycling or similar contexts.

Table 2: Fitness of Measurement Model

Construct	Items	Factor Loadings	Items Deleted	AVE	CR	CA
Privacy (PRI)	PRI1	0.845	PRI 2; PRI 3	0.721	0.885	0.805
	PRI2	0.245				
	PRI3	0.247				
	PRI4	0.893				
	PRI5	0.807				
System Availability (SYS)	SYS1	0.851	SYS4	0.732	0.915	0.872
	SYS2	0.679				
	SYS3	0.938				
	SYS4	0.113				
	SYS5	0.929				
Efficiency (EFF)	EFF1	0.886	EFF2	0.712	0.907	0.861
	EFF2	0.326				
	EFF3	0.839				
	EFF4	0.708				
	EFF5	0.924				
Fulfillment (FUL)	FUL1	0.969	FUL 4	0.863	0.962	0.945
	FUL2	0.805				
	FUL3	0.959				
	FUL4	0.398				
	FUL5	0.969				
Green Knowledge (GREE)	GREE1	0.783		0.663	0.908	0.873
	GREE2	0.787				
	GREE3	0.860				
	GREE4	0.825				
	GREE5	0.815				
User Satisfaction (CS)	CS1	0.854		0.672	0.911	0.878
	CS2	0.812				
	CS3	0.829				
	CS4	0.749				
	CS5	0.851				

4.3 Fornell Larcker

The Fornell-Larcker criterion is a widely adopted method for assessing discriminant validity in structural equation modeling (SEM) (Fornell & Larcker, 1981). Discriminant validity confirms that a construct is distinct and accurately measures its intended concept, differentiating it from other constructs within the model. The criterion assesses this by comparing the square root of the Average Variance Extracted (AVE) for each construct with its correlations to other constructs. These results in Table 3 show that each construct shares more variance with its indicators than with other constructs, thereby meeting the Fornell-Larcker criterion for discriminant validity. This

finding strengthens the model's credibility by confirming that each construct is conceptually distinct. Therefore, it is crucial to define and measure the constructs accurately as this is fundamental to ensuring the robustness of SEM analysis (Faul et al., 2021).

Table 3: The Fornell-Larcker of Each Variable

Variable	CS	EFF	FUL	GREE	PRI	CS
CS	0.826					
EFF	0.520	0.903				
FUL	0.464	0.686	0.902			
GREE	0.542	0.876	0.869	0.870		
PRI	0.448	0.862	0.693	0.775	0.905	
CS	0.686	0.894	0.740	0.814	0.821	0.806

Next, HTMT (Heterotrait-Monotrait Ratio) is a method to evaluate discriminant validity in structural equation modeling (SEM). All the HTMT values are below 1 indicating sufficient discriminant validity between constructs (Hair et al., 2018).

4.4 Structural Model (Direct Relationship)

Table 4 presents the outcomes of the structural model analysis, focusing on the direct effects of the hypothesized relationships between constructs. Key indicators such as standardized path coefficients (β), standard errors (SE), t-values, and p-values are used to evaluate the significance of these hypotheses.

The analysis reveals that H1, privacy has a significant and positive influence on user satisfaction, with a path coefficient of β = 0.378, a t-value of 8.186, and a p-value of 0.000. These results strongly support the hypothesis, indicating that enhancing privacy significantly improves user satisfaction. Meanwhile, H2, system availability exhibits a robust and positive relationship with user satisfaction, as reflected by a path coefficient of β = 0.524, a t-value of 5.981, and a p-value of 0.000. This suggests that system availability is a key determinant of user satisfaction, providing strong support for the hypothesis. The effect of H3, efficiency on user satisfaction is not significant, with a path coefficient of β = -0.098, a t-value of 1.082, and a p-value of 0.280. Since the t-value is below the critical threshold of 1.96 and the p-value exceeds 0.05, this hypothesis is not supported. These findings suggest that efficiency may not have a substantial impact on shaping user satisfaction in this particular study. The relationship between H4, fulfillment and user satisfaction are significant with a path coefficient of β = 0.146, a t-value of 3.629, and a p-value of 0.000. Meanwhile, H5, Green knowledge positively and significantly impacts user satisfaction, as demonstrated by a path coefficient of β = 0.363, a t-value of 5.082, and a p-value of 0.000. The result provides strong support for the hypothesis, underscoring the importance of green knowledge in enhancing user satisfaction.

Overall, the findings demonstrate that privacy, system availability, fulfillment, and green knowledge significantly influence user satisfaction, with varying degrees of impact. However, efficiency does not show a significant relationship with user satisfaction. These results emphasize the need to prioritize privacy, system availability, and green knowledge in efforts to improve user satisfaction. Additionally, the inverse relationship between fulfillment and user satisfaction warrants further exploration to uncover underlying dynamics and potential implications.

Table 4: Structural Model Fitness (Direct Relationship)

H	Direct Effect	β	Std. Error	t-Value	p-Value	Result
H1	Privacy→ User Satisfaction	0.378	0.046	8.186	0.000	**Supported**
H2	System Availability→ User Satisfaction	0.524	0.088	5.981	0.000	**Supported**
H3	Efficiency→ User Satisfaction	-0.098	0.090	1.082	0.280	Not supported
H4	Fulfillment→ User Satisfaction	0.146	0.147	3.629	0.000	**Supported**
H5	Green Knowledge→ User Satisfaction	0.363	0.072	5.082	0.000	**Supported**

4.5. Structural Model (Indirect Relationship)

The analysis of indirect effects explores the moderating role of green knowledge in the relationships between privacy, system availability, efficiency, fulfillment, and user satisfaction. The findings reveal that the indirect effect of privacy on user satisfaction through green knowledge is β = 0.016, with a t-value of 0.738 and a p-value of 0.461. As the t-value is below the critical threshold of 1.96 and the p-value exceeds 0.05, this relationship is not significant, and the hypothesis is not supported. Similarly, the indirect effect of system availability on user satisfaction via green knowledge is β = 0.113, with a t-value of 0.989 and a p-value of 0.323. Since both the t-value and p-value do not meet the required thresholds for significance, this hypothesis is also not supported.

For efficiency, the indirect effect on user satisfaction through green knowledge is β = -0.035, with a t-value of 0.355 and a p-value of 0.723. These results indicate a non-significant relationship, leading to the rejection of the hypothesis. In contrast, the indirect effect of fulfillment on user satisfaction via green knowledge is β = 0.080, with a t-value of 2.368 and a p-value of 0.018. As the t-value exceeds 1.96 and the p-value is below 0.05, this relationship is

significant, and the hypothesis is supported.

In summary, Table 5 demonstrates privacy, system availability, and efficiency do not exhibit significant indirect effects on user satisfaction through green knowledge, fulfillment demonstrates a significant indirect relationship. This highlights the role of green knowledge in enhancing the impact of fulfillment on user satisfaction.

Table 5: Structural Model Fitness (Indirect Relationship)

H	Indirect Effect	β	Std. Error	t-Value	p-Value	Result
H1a	Privacy→Green Knowledge → User Satisfaction	0.016	0.022	0.738	0.461	Not supported
H2a	System Availability → Green Knowledge → User Satisfaction	0.113	0.114	0.989	0.323	Not Supported
H3a	Efficiency → Green Knowledge → User Satisfaction	-0.035	0.097	0.355	0.723	Not Supported
H4a	Fulfillment → Green Knowledge → User Satisfaction	0.080	0.034	2.368	0.018	**Supported**

5. Discussion

For mobile apps in e-waste recycling, privacy, system availability, fulfillment and green knowledge are indicating their positive contributions to user satisfaction. However, Efficiency does not have a significant direct impact on User Satisfaction. In terms of indirect effects, only Fulfillment through Green Knowledge significantly influences User Satisfaction, while the indirect effects of Privacy, System Availability, and Efficiency through Green Knowledge are not significant.

Apps should place significant emphasis on privacy, as it has a positive and significant influence on user satisfaction ($\beta = 0.378$, $p < 0.001$). This suggests that users value apps that protect their personal information, particularly when using e-waste recycling platforms (Ramzan et al., 2021). Privacy concerns are critical because users often need to share sensitive information, such as their location or contact details, when scheduling waste collection (Verma et al., 2025). Ensuring strong data protection mechanisms fosters trust, which in turn enhances satisfaction levels (Achmad et al., 2023). System availability also demonstrates a strong and positive impact on user satisfaction ($\beta = 0.524$, $p < 0.001$). E-waste recycling apps rely on consistent system reliability to provide uninterrupted services such as locating recycling centers or scheduling pickups (Singh & Chaturvedi, 2025). Users report greater satisfaction when apps are consistently available and capable of offering real-time updates, reinforcing the importance of system reliability in service delivery (Alsayed Suliman & Mouselli, 2024). Efficiency, however, does not have a significant impact on user satisfaction ($\beta = -0.098$, $p = 0.280$). This aligns with prior study by Agustina and Suyatno (2024), which highlights that the impact of efficiency varies depending on the context and user expectations. Interestingly, fulfillment positively influences user satisfaction ($\beta = 0.146$, $p < 0.001$). In e-waste recycling, fulfillment is a critical stage. Reflecting to that, failure to meet user expectations, especially concerning environmentally responsible practices can significantly reduce satisfaction levels (Seif et al., 2024). Green knowledge positively influences user satisfaction ($\beta = 0.363$, $p < 0.001$). Users with a higher level of environmental awareness are more inclined to appreciate apps that emphasize sustainability and provide information on the environmental benefits of recycling (Turekova et al., 2020).

Nevertheless, only fulfillment has a significant moderating relationship with green knowledge influencing user satisfaction ($\beta = -0.080$, $p < 0.001$). Negative effects may arise if users perceive that the app's recycling practices are not aligned with sustainability principles (Aguiar Castillo et al., 2018). Therefore, integrating green knowledge into app design can enhance user satisfaction by aligning fulfillment with users' environmental values (Malheiro et al., 2019). In contrast, privacy may exert minimal influence on the relationship between green knowledge and user satisfaction, as user priorities tend to focus on environmental outcomes rather than concerns about data security (Khan et al., 2022). Likewise, while system availability is crucial for usability, it is often regarded as a basic operational necessity. Users of sustainability-focused applications are more inclined to value environmental objectives over the dependability of system uptime (Kumar, 2025). Similarly, efficiency, which includes usability and app speed, is unlikely to serve as a significant moderator due to its lack of direct connection to environmental outcomes. In this context, users are generally willing to tolerate minor inefficiencies provided the app effectively facilitates their environmental goals (Hossain et al., 2021).

6. Conclusion

This study reveals that Privacy, System Availability, Fulfillment, and Green Knowledge significantly enhances User Satisfaction, while Efficiency shows no direct effect. Green Knowledge moderates the positive impact of Fulfillment on User Satisfaction, with no indirect effects observed for Privacy, System Availability, or Efficiency.

Privacy concerns are critical in today's digital landscape, particularly regarding sensitive personal data during the e-

waste recycling process. Furthermore, the performance of a mobile app plays a vital role in user satisfaction; users anticipate a seamless experience with minimal disruptions or technical issues. Research indicates that app reliability directly affects user satisfaction and retention (Ilias et al., 2022). Therefore, ensuring the app operates smoothly with fast load times and minimal crashes can significantly enhance the user experience. This also facilitates the efficient flow of materials through e-waste collection and distribution networks.

Besides, transparency in fulfillment processes is another key factor for building consumer confidence in recycling apps. Users are more inclined to engage with services that clearly communicate how their e-waste will be managed post-collection. This includes details about its transportation, sorting, and eventual trade or recycling (Su, 2024). Features such as tips on proper disposal methods and information on the ecological impact of e-waste provide valuable guidance to users (Ahirwar & Tripathi, 2021). Additionally, updates on local recycling initiatives empower users to make informed decisions aligned with their values (Verma et al., 2025). The integration of efficient distribution systems ensures that collected e-waste reaches recycling centers promptly, reducing delays and minimising environmental risks.

In summary, addressing privacy concerns, ensuring app performance, maintaining transparency in fulfillment processes, integrating efficient logistics, and providing educational resources are critical strategies for enhancing user satisfaction. These efforts promote sustainable behaviour in e-waste recycling mobile distribution platforms while optimizing the trade and distribution systems necessary for effective e-waste management.

7. Theoretical and Practical Contribution

This study advances digital service quality research by investigating how privacy, system availability, efficiency, and fulfillment influence e-waste recycling satisfaction through mobile applications among Generation Z in Malaysia. By integrating these service quality dimensions, it extends existing frameworks to better capture the dynamics of environmentally responsible behaviours facilitated by digital platforms. Additionally, the inclusion of green knowledge as a moderating factor provides novel insights into how environmental awareness shapes the relationship between service quality and user satisfaction.

Practically, the study offers actionable guidance for developers and managers of e-waste recycling apps. It been functional by highlighting the key service attributes that drive Generation Z's satisfaction and engagement, including strong privacy safeguards, system reliability, operational efficiency, and effective service fulfillment. It also emphasizes the critical role of green knowledge in amplifying these effects, suggesting that technological solutions should be complemented with educational campaigns to boost environmental awareness.

From a distribution and logistics viewpoint, the findings stress the need for seamless coordination across the e-waste collection and processing supply chain. Effective fulfillment involves not only reliable app performance but also efficient management of physical channels, including transportation, sorting, and processing. Optimising these logistics is essential for enhancing the efficient and transparent movement of e-waste, thereby fostering greater consumer trust and participation.

These insights can inform policymakers and environmental stakeholders in crafting integrated strategies that combine digital innovation with sustainability education, thereby advancing Malaysia's efforts toward responsible e-waste management among its youth.

8. Limitations and Avenues for Future Research

This study has certain limitations that provide opportunities for further exploration. First, the reliance on a quantitative approach, while suitable for identifying statistical relationships, may not fully capture the nuanced perspectives of respondents regarding e-waste recycling behaviours. Future research could adopt mixed-method or qualitative approaches to provide deeper insights into the motivations and challenges faced by users.

Second, the study employs a purposive sampling method, focusing exclusively on Generation Z, which limits the generalizability of the findings to other demographic groups. Subsequent studies could expand the sample to include diverse age cohorts, such as Millennials and Generation X, to examine generational differences in attitudes toward e-waste recycling and mobile application use.

Lastly, this research is confined to evaluating the direct and moderating effects within the framework of the E-SERVQUAL model and green knowledge. Future studies could explore additional variables, such as cultural factors, perceived behavioural control, or social influence, to address existing gaps and further enrich the understanding of technology adoption for sustainable practices.

References

Achmad, A., Muliadi, M., Areni, I., Palantei, E., Hadis, M. S., & Achmad, A. D. (2023). Smart Electrical Devices Control with Intrusion Detection Alert. *International Journal of Interactive Mobile Technologies*, *16*(5), 1865–7923. https://doi.org/10.3991/ijim.v16i05.26737

Aguiar Castillo, L., Rufo Torres, J., De Saa Pérez, P., & Pérez

Jiménez, R. (2018). How to encourage recycling behaviour? The case of WasteApp: a gamified mobile application. *Sustainability*, *10*(5), 1–20. https://doi.org/10.3390/su10051544

Agustina, D., & Suyatno, D. F. (2024). Integration of E-Service Quality (E-Servqual) And Importance Performance Analysis (IPA) Methods on BTN Mobile Application User Satisfaction. *Journal of Emerging Information System and Business Intelligence*, *5*(3), 90–100. https://doi.org/10.26740/jeisbi.v5i3.62192

Ahirwar, R., & Tripathi, A. K. (2021). E-waste management: A review of recycling process, environmental and occupational health hazards, and potential solutions. *Environmental Nanotechnology, Monitoring & Management*, *15*, 100409.

Alalwan, A. A., Algharabat, R. S., Baabdullah, A. M., Rana, N. P., Qasem, Z., & Dwivedi, Y. K. (2020). Examining the impact of mobile interactivity on customer engagement in the context of mobile shopping. *Journal of Enterprise Information Management*, *33*(3), 627–653. https://doi.org/10.1108/JEIM-07-2019-0194/FULL/HTML

Alsayed Suliman, B., & Mouselli, S. (2024). The quality of e-payment services offered by mobile companies: the Syrian evidence. *Cogent Business and Management*, *11*(1), 2365998. https://doi.org/10.1080/23311975.2024.2365998

Andeobu, L., W. S., & G. S. (2021). An assessment of e-waste generation and environmental management of selected countries in Africa, Europe and North America: A systematic review. *Science of The Total Environment*, *792*, 148078. https://doi.org/10.1016/j.scitotenv.2021.148078

Bernama. (2023). *Maxis-ERTH recycling campaign helps prevent five tonnes of e-waste ending up in landfills*.

Campbell, S., Greenwood, M., Prior, S., Shearer, T., Walkem, K., Young, S., Bywaters, D., & Walker, K. (2020). Purposive sampling: complex or simple? Research case examples. *Journal of Research in Nursing*, *25*(8). https://doi.org/10.1177/1744987120927206

Desy, S., Ika, L., Arifin, M., Nurzengky, I., Arita, M., Musril, Z., & Rossi, I. (2021). Web-based animation video for student environmental education at elementary schools. *International Journal of Interactive Mobile Technologies*, *15*(11), 66–80. https://doi.org/10.3991/ijim.v15i11.22023

DOE. (2022). *E-waste Management in Malaysia. Department of Environment, Ministry of Environment and Water*.

Faul, F., E. E., B. A., & L. A. G. (2009). Statistical power analyses using G* Power 3.1: Tests for correlation and regression analyses. *Behavior Research Methods*, *41*(4), 1149–1160. https://doi.org/doi:10.3758/BRM.41.4.1149

Fornell, C., & Larcker, D. F. (1981). Evaluating structural equation models with unobservable variables and measurement error. *Journal of Marketing Research*, *18*(1), 39–50. https://doi.org/10.2307/3151312

Gleim, M., Smith, J., Andrews, D., & Cronin Jr, J. J. (2013). Against the green: A multi-method examination of the barriers to green consumption. *Journal of Retailing*, *89*(1), 44–61. https://doi.org/10.1016/j.jretai.2012.10.001

Hair, J. F., Risher, J. J., Sarstedt, M., & Ringle, C. M. (2019). When to use and how to report the results of PLS-SEM. In *European Business Review* (Vol. 31, Issue 1, pp. 2–24). Emerald Group Publishing Ltd.

Hair, J., Harrison, D., Marketing, J. R.-B. J. of, & 2018, undefined. (2018). Marketing research in the 21st century: Opportunities and challenges. *Brazilian Journal of Marketing*, *17*. https://doi.org/10.5585/bjm.v17i5.4173

Hasal, M., Nowaková, J., Ahmed Saghair, K., Abdulla, H., Snášel, V., & Ogiela, L. (2021). Chatbots: Security, privacy, data protection, and social aspects. *Concurrency and Computation: Practice and Experience*, *33*(19). https://doi.org/10.1002/cpe.6426

Hashim, R., Salleh, N. A., Ibrahim, J. A., & Cooper, S. (2025). E-waste management practices through the eyes of responsible departments at Malaysian public universities. *Journal of Advanced Research in Applied Sciences and Engineering Technology*, *52*(1), 309–319. https://doi.org/10.37934/araset.52.1.309319

Hawkins, D. L., & Hoon, S. (2019). The impact of customer retention strategies and the survival of small service-based businesses. *SSRN*, 3445173. https://doi.org/10.2139/ssrn.3445173

Hermann, E., Williams, G., & Puntoni, S. (2024). Deploying artificial intelligence in services to AID vulnerable consumers. *Journal of the Academy of Marketing Science*, *52*(5), 1431–1451. https://doi.org/10.1007/s11747-023-00986-8

Hill, N., & Alexander, J. (2017). The handbook of customer satisfaction and loyalty measurement. *The Handbook of Customer Satisfaction and Loyalty Measurement*, 1–288. https://doi.org/10.4324/9781315239279/HANDBOOK-CUSTOMER-SATISFACTION-LOYALTY-MEASUREMENT-JIM-ALEXANDER-NIGEL-HILL

Huenerfauth, A. M. (2014). Mobile Technology Applications for Manufacturing, Reduction of Muda (Waste) and the Effect on Manufacturing Economy and Efficiency. *International Journal of Interactive Mobile Technologies*, *8*(4), 20–23. https://doi.org/https://doi.org/10.3991/ijim.v8i4.3797

Ighomereho, S., Fetuga, O., Salome, I. O., David, A. O., Iyabode, O. M., Benson, I. A., Grace, I. O., & Maryam, F. O. (2023). Post COVID-19 and Naira Redesign in Nigeria: Implications for E-banking Service Quality Attributes and Outcomes. *International Journal of Academic and Applied Research*, *7*(4), 56–67.

Ikhsan, R. B., Fernando, Y., Gui, A., & Fernando, E. (2024). The power of online reviews: Exploring information asymmetry and its impact on green product purchasing behavior. *International Journal of Consumer Studies*, *48*(3). https://doi.org/10.1111/IJCS.13050

Ilias, I., Ramli, S., Wook, M., & Hasbullah, N. A. (2022). Factors Influencing Users' Satisfaction Towards Image Use in Social Media: A PLS-SEM Analysis. *International Journal of Interactive Mobile Technology*, *16*(15), 172–186. https://doi.org/10.3991/ijim.v16i15.32555

Iparraguirre-Villanueva, O., Tuesta-Pereda, L., Tapia-Chavez, E., & Cabanillas-Carbonell, M. (2023). Improving Environmental Sustainability: A Geolocation-Based Mobile Application to Optimize the Recycling Process. *International Journal of Interactive Mobile Technologies*, *17*(23), 32–48. https://doi.org/10.3991/ijim.v17i23.44417

Ismail, H., & Hanafiah, M. M. (2020). A review of sustainable e-waste generation and management: Present and future perspectives. *Journal of Environmental Management*, *264*, 110495. https://doi.org/10.1016/j.jenvman.2020.110495

Jamal, A. (2004). Retail banking and customer behaviour: A study of

self concept, satisfaction and technology usage. *The International Review of Retail, Distribution and Consumer Research*, *14*(3), 357–379. https://doi.org/10.1080/0959396041000167838 1

Joy, C., Santillan, P., Lawrence, X., Mendoza, D., & Tadeo, J. B. (2023). Microanalysis of E-Money Transfer Services through E-Servqual Approach: A Basis for Enhanced Customer Satisfaction Strategy. *International Journal of Business, Technology and Organizational Behavior*, *3*(2), 119–136.

Jr, J. H., Hult, G., Ringle, C., Sarstedt, M., & Danks, N. (2021). *Partial least squares structural equation modeling (PLS-SEM) using R: A workbook*. Springer. https://library.oapen.org/handle/20.500.12657/51463

Khan, R. U., Salamzadeh, Y., Iqbal, Q., & Yang, S. (2022). The Impact of Customer Relationship Management and Company Reputation on Customer Loyalty: The Mediating Role of Customer Satisfaction. *Journal of Relationship Marketing*, *21*(1), 1–26. https://doi.org/10.1080/15332667.2020.1840904

Kumar. (2025). A Comprehensive Review of MCDM Methods, Applications, and Emerging Trends. *Decision Making Advances*, *3*(1), 185–199. https://doi.org/10.31181/dma31202569

Kuppelwieser, V. G., Putinas, A. C., & Bastounis, M. (2019). Toward Application and Testing of Measurement Scales and an Example. *Sociological Methods and Research*, *48*(2), 326–349. https://doi.org/10.1177/0049124117701486

Lee, G. G., & Lin, H. F. (2005). Customer perceptions of e-service quality in online shopping. *International Journal of Retail and Distribution Management*, *33*(2), 161–176. https://doi.org/10.1108/09590550510581485/FULL/

Lopes, J. M. M., Gomes, S., & Trancoso, T. (2024). Navigating the green maze: insights for businesses on consumer decision-making and the mediating role of their environmental concerns. *Sustainability Accounting, Management and Policy Journal*, *15*(4), 861–883. https://doi.org/10.1108/SAMPJ-07-2023-0492/FULL/HTML

Malheiro, B., Silva, M. F., Ferreira, P., & Guedes, P. (2019). Learning engineering with EPS@ISEP developing projects for smart sustainable cities. *International Journal of Engineering Pedagogy*, *9*(4), 33–49. https://doi.org/10.3991/ijep.v9i4.10259

Momeni, M. (2024). Artificial Intelligence and Political Deepfakes: Shaping Citizen Perceptions Through Misinformation. *Journal of Creative Communications*, 09732586241277335. https://doi.org/10.1177/09732586241277335

Pang, W. , Y. S. , Q. J. , & A. M. (2025). Research on the Incentive Model of Express Packaging Recycling Based on the Three-Party Game Model. *IETI Transactions on Data Analysis and Forecasting*, *2*(4), 59–68.

Parasuraman, A. (1985). A Conceptual Model Service Quality and Its Implications for Future Research. *Journal of Marketing*, *42*.

Parasuraman, A., Zeithaml, V. A., & Malhotra, A. (2005). E-S-QUAL a multiple-item scale for assessing electronic service quality. *Journal of Service Research*, *7*(3), 213–233. https://doi.org/10.1177/1094670504271156

Parasuraman, A., Zeithaml, V., & Berry, L. L. (1988). Servqual: A multiple-item scale for measuring consumer perc. *Journal of Retailing*, *64*(1), 12.

Poudel, O., Acharya, P., & Simkhada, D. (2023). Customers' Trust in E-payment: The Influence of Security and Privacy. *BMC Journal of Scientific Research*, *6*(1), 97–112.

Prakash, C., Yadav, R., & Rathee, S. (2024). Modeling of electronic-waste recycling intentions among Generation Z. *Smart Electric and Hybrid Vehicles: Fundamentals, Strategies and Applications*, 128–141. https://doi.org/10.1201/9781003495574-7/MODELING-ELECTRONIC-WASTE-RECYCLING-INTENTIONS-AMONG-GENERATION-CHAND-PRAKASH-RITU-YADAV-SARITA-RATHEE

Ramzan, S., Liu, C., Xu, Y., Munir, H., & Gupta, B. (2021). The adoption of online e-waste collection platform to improve environmental sustainability: An empirical study of Chinese millennials. *Management of Environmental Quality: An International Journal*, *32*(2), 193–209. https://doi.org/10.1108/MEQ-02-2020-0028/FULL/HTML

Robustin, T. P. (2023). E-ServQual role in Creating Consumer Trust towards Shopee Marketplace during the Covid-19 Pandemic. *Journal of Management & Marketing Review*, *8*(2). https://doi.org/10.35609/jmmr.2023.8.2(2)

Saeliw, A., Hualkasin, W., Puttinaovarat, S., & Khaimook, K. (2019). Smart car parking mobile application based on RFID and IoT. *International Journal of Interactive Mobile Technologies*, *13*(5), 4–14. https://doi.org/10.3991/ijim.v13i05.10096

Sarstedt, M., Ringle, C., & Hair, J. F. (2021). Partial least squares structural equation modeling. In Handbook of market research. In *Cham: Springer International Publishing*. Cham: Springer International Publishing. https://doi.org/10.1007/978-3-319-05542-8_15-2

Seif, R., Salem, F. Z., & Allam, N. K. (2024). E-waste recycled materials as efficient catalysts for renewable energy technologies and better environmental sustainability. *Environment, Development and Sustainability*, *26*(3), 5473–5508. https://doi.org/10.1007/s10668-023-02925-7

Shumon, M. R. H., Ahmed, S., & Islam, M. T. (2014). Electronic waste: present status and future perspectives of sustainable management practices in Malaysia. *Environmental Earth Sciences*, *72*(7). https://doi.org/10.1007/s12665-014-3129-5

Singh, A. P., & Chaturvedi, A. (2025). Technological solutions for E-waste management and disposal. In *taylorfrancis.com*. CRC Press. https://doi.org/10.1201/9781003606635-71/TECHNOLOGICAL-SOLUTIONS-WASTE-MANAGEMENT-DISPOSAL-ADITYA-PRATAP-SINGH-AKSHAT-CHATURVEDI

Stevic, Z., Nunic, D., Badi, I., & Karabasevic, D. (2022). Evaluation of dimensions of SERVQUAL model for determining quality of processes in reverse logistics using a Delphi–Fuzzy PIPRECIA model. *Rom. J. Econ. Forecast*, *25*(1), 139–159.

Su, Q. (2024). Study on the Willingness of Mobile Advertisement Users Based on TAM Model. *IETI Transactions on Data Analysis and Forecasting*, *2*(1), 63–71. https://doi.org/10.3991/itdaf.v2i1.49105

Turekova, I., Bilcikova, J., Bilcik, A., & Markova, I. (2020). Implementation of environmental issues in teaching the subject of technical education at primary schools. *International Journal of Engineering Pedagogy*, *10*(4), 93. https://doi.org/10.3991/ijep.v10i4.13077

Verma, S., Yadav, R., Andrade, H. D. S., & Yadav, S. K. (2025). Understanding household hesitancy: Analysis Of E-waste recycling application adoption among indian recyclers. *Cleaner Waste Systems*, *11*, 100265. https://www.sciencedirect.com/science/article/pii/S2772912525000636

Wulandari, P., Dzakiyullah, N. R., Ratnasari, A., & Heksaputra, D. (2024). Analysis of MAXIM Application Service Quality on

User Satisfaction using the E-Service Quality Method. *Jurnal Sisfokom (Sistem Informasi Dan Komputer)*, *13*(3), 323–329.

Yahya, O., Alrikabi, H., & Faezipour, M. (2020). Using internet of things application for disposing of solid waste. *International Journal of Interactive Mobile Technologies*, *14*(13), 4–18. https://doi.org/https://doi.org/10.3991/ijim.v14i13.13859

Zainuddin, S. A., Abdullah, T., Ibrahim, M. A. H., Nawi, N. C., Nasir, N. A. M., Latef, A. S. A., & Musa, Z. C. (2024). Analyzing Global Research Trends in Technology and E-Waste Management: A Bibliometric Perspective. In *Technology-Driven Business Innovation: Unleashing the Digital Advantage* (Vol. 2, pp. 443–453). Springer. https://doi.org/10.1007/978-3-031-62656-2_39

Zeithaml, V., Parasuraman, A., & Malhotra, A. (2002). Service quality delivery through web sites: a critical review of extant knowledge. *Ournal of the Academy of Marketing Science*, *30*(4), 362–375. https://doi.org/10.1177/009207002236911

Zhang, G., Wang, L., & Meng, H. (2024). Environmental knowledge level and consumer behavior regarding green fashion: a moderated mediation model. *Asia Pacific Journal of Marketing and Logistics*, *36*(4), 977–992. https://doi.org/10.1108/APJML-07-2023-0637/FULL/HTML