

*Research Article*

Perceived Helpfulness of Automated Waste Sorting in Indonesia Is Associated with Pickup-Service Reliability and Waste-Sorting Behavior

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Abstract: Digital technologies are increasingly proposed to improve waste management, yet their uptake depends not only on technical feasibility but also on how people perceive their usefulness under existing service conditions. This study uses a quota-based online survey of 1,000 adults across 33 province-level fielding strata to examine the perceived helpfulness of automated waste-sorting technology in Indonesia, with the Papua region grouped into one fielding category. The main outcome variable captures respondents' ordered ratings of whether automated sorting would help them, ranging from very unnecessary to very helpful. The analysis combines descriptive statistics, Multiple Correspondence Analysis (MCA), chi-square tests, Cramer's V, and Pearson residual analysis to explore how perceived helpfulness is associated with sociodemographic characteristics, self-reported waste practices, and everyday service conditions. Overall, 69.7% and 20.2% of respondents rated automated sorting as very helpful and helpful, respectively, while 7.7% and 2.4% rated it as neutral and unhelpful, respectively. Perceived helpfulness was generally higher among younger respondents, those who were already engaged in waste sorting, and those who reported more reliable pickup services. Exploratory MCA results suggested recurring patterns linking favorable perceptions with active sorting behavior and more reliable service contexts, whereas less favorable perceptions were more common where pickup reliability was uncertain or weak. These findings suggest that public receptivity to automated waste sorting in Indonesia is associated not only with attitudes toward technology but also with the quality of routine waste services. The results should be interpreted as exploratory evidence from an online quota-based sample rather than as a nationally representative estimate of technology acceptance.

Keywords: Automated waste sorting; Indonesia; Perceived helpfulness; Pickup-service reliability; Waste-sorting behavior

1. Introduction

Solid waste management (SWM) remains a persistent sustainability challenge for rapidly urbanizing economies. Digital technologies, such as smart bins, automated sorting systems, sensor-enabled collection, and app-based reward platforms, are increasingly being promoted to improve collection, separation, and transparency. However, their practical value depends not only on technical performance but also on whether people perceive them as useful within the

service environments they encounter in everyday life (Ogawa et al., 2023; Shan et al., 2025; Zhao et al., 2025). This socio-technical question is especially important in Indonesia, where digital waste initiatives are emerging amid uneven source separation, fragmented local governance, and substantial regional variation in collection services (Fatimah et al., 2020; Harfadli et al., 2025; World Bank, 2019).

Indonesia's waste system continues to rely heavily on landfilling, while weak infrastructure and limited household participation constrain recycling and composting (Fatimah et al., 2020; Harfadli et al., 2025). Low levels of source separation reduce the effectiveness of downstream recovery technologies, and variations in local regulations, financing, equipment, and data systems limit the performance of community waste-bank programs (Budiyarto et al., 2025). Evidence from Indonesian cities likewise shows that infrastructure alone cannot compensate for weak education, inconsistent service routines, or limited opportunities for sustained participation (Kurniawan et al., 2023; Putri & Hanum, 2021; Sembiring et al., 2024; Supriyadi et al., 2000). These conditions create an uneven foundation for digital transition and make existing service quality central to how the proposed automation is likely to be perceived.

Digitalization can support waste-flow tracking, recycling compliance, route management, and user engagement through sensor networks, mobile platforms, and integrated monitoring systems (Bastos et al., 2022; Rejeb & Zailani, 2023). However, adoption in developing-country settings is frequently limited by capital costs, infrastructure gaps, skills shortages, and governance constraints (Tan & Taeihagh, 2020). Similarly, technology assessment studies published in the *International Journal of Technology* demonstrate that waste-sector innovations must be evaluated against operational feasibility and local system readiness rather than technical potential alone (Prabowo et al., 2019; Shukor et al., 2018). Taken together, this literature indicates that when embedded in reliable and understandable everyday services, smart waste systems are more likely to be credible to users.

Public receptivity also depends on social and behavioral conditions. Research on sorting and recycling links participation to household roles, service access, social norms, prior experience, and the convenience of available infrastructure (Barr et al., 2001; Knickmeyer, 2020; Miafodzyeva & Brandt, 2013; Nguyen et al., 2015; Tonglet et al., 2004). Education and income do not consistently translate into environmental action without enabling infrastructure, incentives, and a sense of behavioral control (Asteria & Herdiansyah, 2022; Botetzagias et al., 2015; Hansmann & Binder, 2020; Melese et al., 2025; Piao & Managi, 2024). Behavioral research identifies attitudes, subjective norms, and perceived behavioral control as important antecedents of waste-sorting intentions (Botetzagias et al., 2015). Later technology-acceptance frameworks identify performance expectancy, effort expectancy, social influence, and facilitating conditions as important determinants of technology acceptance and use (Venkatesh et al., 2003), while environmental-technology studies additionally highlight institutional trust, perceived fairness, and familiarity (Caferri et al., 2023; Liu & Hsu, 2022). Therefore, in a setting where automated sorting is not yet widely deployed, perceived helpfulness is best treated as an anticipatory indicator of public receptivity, not as observed adoption or implementation readiness.

Despite growing interest in digital waste management, limited evidence explains how people in emerging economies evaluate automated sorting before direct experience with the technology. Existing studies have focused more on actual sorting or recycling behavior than on how anticipatory perceptions of automation co-occur with routine waste practices and service conditions. This study addresses this gap by examining the perceived helpfulness of automated waste sorting among 1,000 Indonesian adults recruited through a quota-based online survey across 33 province-level fielding strata. It evaluates associations with sociodemographic characteristics, self-reported sorting behavior, pickup reliability, and six grouped island-region categories using descriptive statistics, multiple correspondence analysis, chi-square tests, Cramer's V, and Pearson residual analysis. All relationships are interpreted as exploratory associations rather than causal effects or respondent classifications.

This study contributes by linking perceptions of automation to the service and behavioral

contexts in which the technology would operate, combining complementary descriptive and association-based analyses, and distinguishing favorable perceptions from demonstrated acceptance or readiness. The remainder of this paper is organized as follows: The survey design, variable construction, and analytical framework are described in Section 2. The descriptive findings, exploratory MCA patterns, and statistical association tests are presented in Section 3. Section 4 discusses the findings in relation to international evidence and policy design, and Section 5 concludes the study with implications, limitations, and directions for future research.

2. Data and Methodology

2.1 Survey Design and Analysis of Variables

This study uses data from a quota-based online survey conducted in Indonesia in October 2024 through TSURVEY (Telkomsel), an online survey platform. The fieldwork targeted adults aged 20 years and older and was configured using gender, age-range, and province or province-group filters within the platform. Internal project files indicate that the final analytical dataset was assembled from 36 region-by-gender campaign files that yielded 1,000 valid completed responses. The resulting dataset covers 33 province-level fielding strata, with the Papua region grouped into a single fielding category. These fielding strata were recoded into six grouped island-region categories for analysis; neither the fielding strata nor the analytical groups support province-level population inference. Several geographic cells were grouped at the fielding stage for operational reasons, and five provinces were not covered because, according to communication with the survey provider during fieldwork, the available panel did not sufficiently match the requested quota profile. The results should be interpreted as exploratory evidence from an online quota-based sample rather than as nationally representative estimates because the sample was recruited online rather than from a probability frame.

The questionnaire was administered using a structured skip-logic design in Bahasa Indonesia. Respondents outside the analytical age range were screened out, and later question blocks were routed based on respondents' stated involvement in household waste management and their reported familiarity with waste-bank services. The main outcome variable is Autosort, which captures respondents' perceived helpfulness of a hypothetical automated waste-sorting technology. In the original Indonesian questionnaire, respondents were asked: "*Apakah Anda akan merasa terbantu apabila petugas sampah di lingkungan Anda memakai mesin pemilah sampah otomatis sehingga Anda tidak perlu memilah sampah?*" The English translation was as follows: "Would you find it helpful if waste collectors in your neighborhood used an automated waste-sorting machine so that you would not need to sort waste yourself?" The item was presented as text only; no image, animation, or implementation scenario was shown to respondents.

Autosort is interpreted as an anticipatory measure of perceived helpfulness or public receptivity rather than as observed adoption, willingness to pay, or demonstrated implementation readiness because automated sorting technology is not yet widely deployed in Indonesia. Other variables include gender, age group, educational attainment, monthly income, household size, housing type, self-reported waste-sorting behavior, primary waste disposal or storage location, perceived pickup-service reliability, and grouped island-region location. TSURVEY also supplied campaign-level response rate metrics for 17 underlying survey IDs, with reported values ranging from 0.06% to 0.33% and averaging 0.16%. Because the underlying denominator was not documented in a form directly comparable to conventional survey response-rate reporting, these values are reported only as provider-reported platform metrics.

For transparency, this article draws on the same underlying $n = 1,000$ survey dataset as our earlier conference paper (Pandyaswargo et al., 2025). However, it differs in its specific focus on the Autosort item, the grouped quota-fielding structure, the explicit recoding strategy, and the more conservative exploratory interpretation adopted here.

Table 1 Summary of the characteristics of the respondents and survey variables used in the analysis

Variable	Category	n	%
Gender	Male	501	50.1
	Female	499	49.9
Age group	20s	372	37.2
	30s	366	36.6
	40+	262	26.2
	Up to high school	426	42.6
Educational attainment	Diploma/Bachelor	536	53.6
	Master's degree or higher	38	3.8
	< 5 million	724	72.4
Monthly income (IDR)	5–10 million	206	20.6
	> 10 million	70	7.0
	Java	564	56.4
Island-region group	Sumatra	213	21.3
	Kalimantan	63	6.3
	Sulawesi-Gorontalo	73	7.3
	Bali-NTB-NTT	54	5.4
	Maluku-Papua	33	3.3
	1–2 persons	150	15.0
Household size	3–4 persons	510	51.0
	5+ persons	340	34.0
	Modest formal	309	30.9
Housing*	Shared/compact	217	21.7
	Large/planned	150	15.0
	Traditional/other	324	32.4
Waste sorting behavior	Yes	457	45.7
	Sometimes	343	34.3
	No	200	20.0
	Very helpful	697	69.7
Autosort helpfulness	Helpful	202	20.2
	Neutral	77	7.7
	Unhelpful	24	2.4
	At-home bin	611	61.1
Waste location	Community collection points	152	15.2
	Stored indoors until pickup	117	11.7
	Open-space disposal	107	10.7
	Other managed locations	13	1.3
Reliability of pickup service	Yes	669	66.9
	No	245	24.5
	Do not know	86	8.6

*Low-frequency categories were collapsed before inferential analysis to improve cell stability and align the analysis with the survey deployment's grouped quota-fielding structure.

2.2 Multiple Correspondence Analysis

Multiple Correspondence Analysis (MCA) was used as an exploratory technique for visualizing associations among categorical modalities rather than for assigning respondents to data-derived groups. MCA is well suited to identifying recurring configurations in multidimensional categorical data (Abdi & Valentin, 2007; Greenacre, 2017). In this study, the MCA plots

are interpreted as descriptive maps of modality association, and the resulting configurations are discussed as exploratory patterns rather than as respondent classifications.

The MCA design was organized into three analytical sets that separate individual predispositions, household service context, and broader geographic context. Set A combines age, gender, education, waste-sorting behavior, waste disposal or storage location, and Autosort. Set B combines household size, housing type, income, waste-sorting behavior, pickup-service reliability, and Autosort. Set C combines grouped island-region location, education level, income level, waste disposal or storage location, and pickup-service reliability.

Before the inferential analysis, analytically sparse categories were collapsed on substantive grounds to improve cell stability. This included merging the two rare negative Autosort categories into a single Unhelpful category, grouping age into 20s, 30s, and 40+, collapsing income into three levels, recoding the 33 province-level fielding strata into six grouped island-region categories, consolidating detailed housing responses into four broader dwelling-context groups, and simplifying the waste-location variable into five operational categories. The same recoding rules were then applied consistently across the descriptive, contingency-table, residual, and MCA analyses.

Table 2 Analytical variables and recoded category definitions used in the revised analysis

Variable	Analytical definition	Recoded categories (n)
Age	Age group	20s (n = 372); 30s (n = 366); 40+ (n = 262)
Education	Educational attainment	Up to high school (n = 426); Diploma/Bachelor (n = 536); Master's degree or higher (n = 38)
Gender	Gender	Male (n = 501); Female (n = 499)
Income	Monthly income	<5 million IDR (n = 724); 5–10 million IDR (n = 206); >10 million IDR (n = 70)
Region	Island-region group	Java (n = 564); Sumatra (n = 213); Kalimantan (n = 63); Sulawesi-Gorontalo (n = 73); Bali-NTB-NTT (n = 54); Maluku-Papua (n = 33)
Autosort	Perceived helpfulness of automated waste sorting	Very helpful (n = 697); Helpful (n = 202); Neutral (n = 77); Unhelpful (n = 24)
Hhsize	Number of people living in the household	1–2 persons (n = 150); 3–4 persons (n = 510); 5+ persons (n = 340)
Housing	Housing type	Modest formal housing (n = 309); shared/compact housing (n = 217); large/planned housing (n = 150); traditional/other (n = 324)
WLoc	Primary waste disposal or storage location	At-home bin (n = 611); community collection point (n = 152); indoor storage until pickup (n = 117); open-space disposal (n = 107); other managed location (n = 13)
Opickup	Pickup service reliability	Yes (n = 669); No (n = 245); Do not know (n = 86)
Sort	Self-reported waste sorting behavior	Yes (n = 457); Sometimes (n = 343); No (n = 200)

2.3 Chi-square Test and Cramer's V Test

Following the descriptive and MCA analyses, we evaluated the selected variable pairs using chi-square tests of independence. Cramer's V was used as a descriptive measure of association strength, mainly to compare the relative magnitude of statistically significant relationships rather than to imply strong substantive effects. The expected cell diagnostics were checked for the contingency tables and are summarized in Table 4.

The inferential analysis is interpreted as exploratory rather than confirmatory. It is used to assess whether several policy-relevant associations are statistically nonrandom after sparse categories are recoded, while the effect-size estimates are used to keep the interpretation proportionate to the data.

2.4 Pearson Residual Analysis (PRA)

To identify which category combinations contributed most strongly to the reported associations, we calculated the Pearson residuals for selected contingency tables and visualized them in heatmap form. A positive residual indicates that a category combination appears more frequently than expected under independence, whereas a negative residual indicates the opposite. The residual heatmaps and Table 5 were generated from the same recoded analytical dataset and are interpreted as descriptive follow-up tools rather than as standalone evidence.

In practice, larger absolute residual values indicate more pronounced departures from independence; however, they should still be interpreted together with the underlying crosstable, effect sizes, and category frequencies.

After cleaning and recoding the responses, the final workflow combined descriptive statistics, MCA, chi-square tests, Cramer's V, and Pearson residual analysis. This sequence allows the manuscript to first present the distribution of responses, then explore multivariate modality patterns, and finally examine selected bivariate relationships in a more transparent and conservative manner.

3. Results

The results are presented in four steps. First, descriptive statistics summarize how respondents in the online quota-based sample evaluated automated waste sorting, reported waste-sorting behavior, and described pickup-service reliability. Second, the MCA is used to explore recurring patterns of association among demographic, behavioral, household, and island-region modalities. Third, the chi-square test and Cramer's V were used to assess the strongest bivariate relationships. Fourth, the most pronounced category combinations within the retained contingency tables are interpreted using Pearson residual heatmaps. The findings are interpreted as exploratory evidence on public receptivity rather than as nationally representative estimates of technology acceptance.

3.1 Descriptive Statistics and Cross-tabulation Analysis

The perceived helpfulness of automated waste sorting was generally high in the online quota-based sample. Of the 1,000 respondents, 69.7% and 20.2% rated automated sorting as very helpful and helpful, respectively, while 7.7% and 2.4% rated it as neutral and unhelpful, respectively. Self-reported sorting behavior was also relatively common: 45.7% reported sorting waste, 34.3% reported sorting occasionally, and 20.0% reported not sorting. Reported pickup-service reliability varied more clearly across grouped service contexts, suggesting that favorable views of automation may co-exist with uneven evaluations of everyday waste collection.

Regional disparities were also pronounced. Reliable pickup was reported by 72.9% of respondents in Java, 56.8% in Sumatra, and 51.5% in Maluku-Papua, while open-space disposal remained comparatively more common in Bali-NTB-NTT, Maluku-Papua, and parts of Sumatra. These descriptive findings indicate that favorable perceptions co-occur with differences in

demographic characteristics and service environments.

Figure 1 summarizes one of the clearest descriptive patterns in the data: respondents in their 20s were the most likely to rate automated sorting as very helpful (73.9%), compared with 71.6% among respondents in their 30s and 61.1% among respondents aged 40 and above. Older respondents were not uniformly negative, but they were more likely to choose the less enthusiastic “helpful” category, indicating lower support intensity than outright rejection.

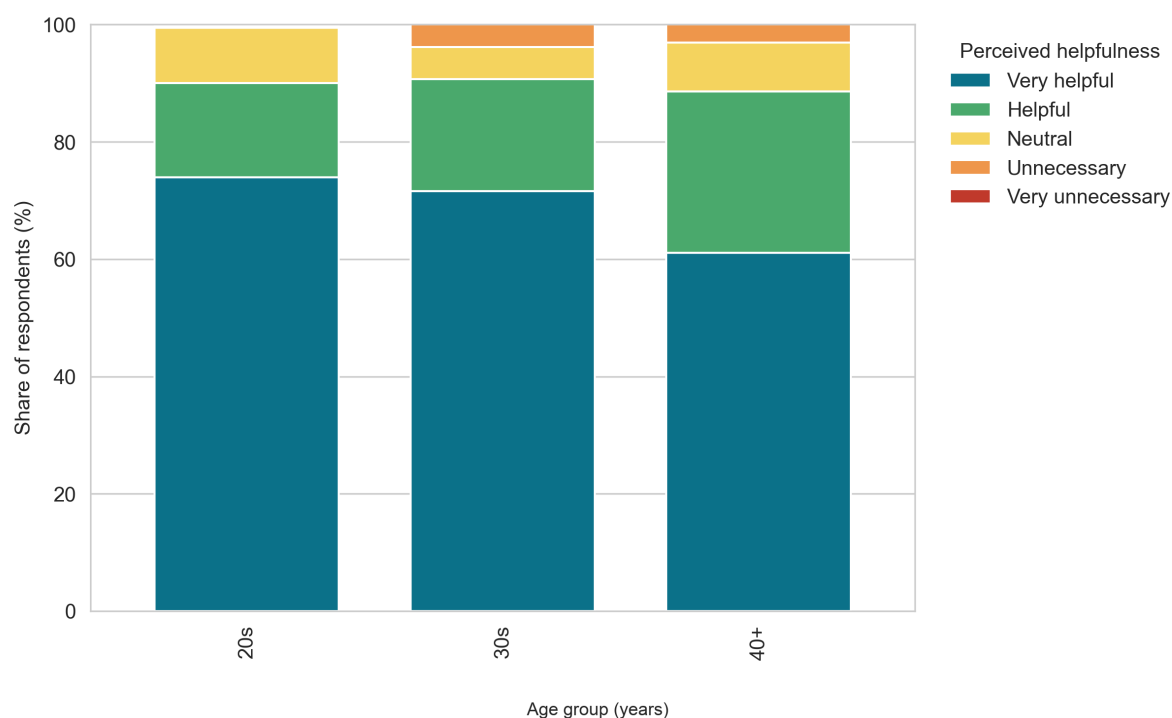


Figure 1 Perceived helpfulness of automated sorting according to age group

3.2 Multiple Correspondence Analysis (MCA)

3.2.1 Analytical structure

Table 3 summarizes the variables included in the three MCA models: Set A (demographics and waste behavior), Set B (household characteristics and service perception), and Set C (regional social-ecological context). The first two dimensions explained 16.6% of inertia for Set A, 17.4% for Set B, and 15.6% for Set C. Although these shares are modest, they fall within the expected range for behavioral data with multiple categorical variables and still reveal meaningful relational patterns among demographic characteristics, household structure, service conditions, and waste management behavior.

3.2.2 MCA plot output of set A—demographics and waste behavior

The MCA results for Set A (Figure 2) are interpreted as exploratory patterns of association among categorical modalities without classifying respondents into separate groups.

Favorable perceptions alongside active sorting. Younger age categories and more active waste-sorting behavior appear closer to favorable Autosort responses in the MCA space. This suggests an exploratory configuration in which prior engagement with sorting practices coincides with a stronger perceived helpfulness of automation. The pattern is also consistent with studies showing that household day-to-day waste handling remains socially embedded and often gendered (Amoah et al., 2023).

Table 3 Variables used in each MCA set

Variable	Demographics and Waste Behavior	Household Characteristics and Service Perception	Regional Socio-Ecological Context
Age	✓		
Perceived helpfulness of automated sorting (Autosort)	✓	✓	
Educational attainment (Edu)	✓		✓
Gender	✓		
Household size (Hhsize)		✓	
Housing type (Htype)		✓	
Monthly income (inc)		✓	✓
Pickup service reliability (Opickup)		✓	✓
Primary waste disposal location (WLoc)	✓		✓
Self-reported waste sorting behavior (Sort)	✓	✓	✓
Island-region group (region)			✓

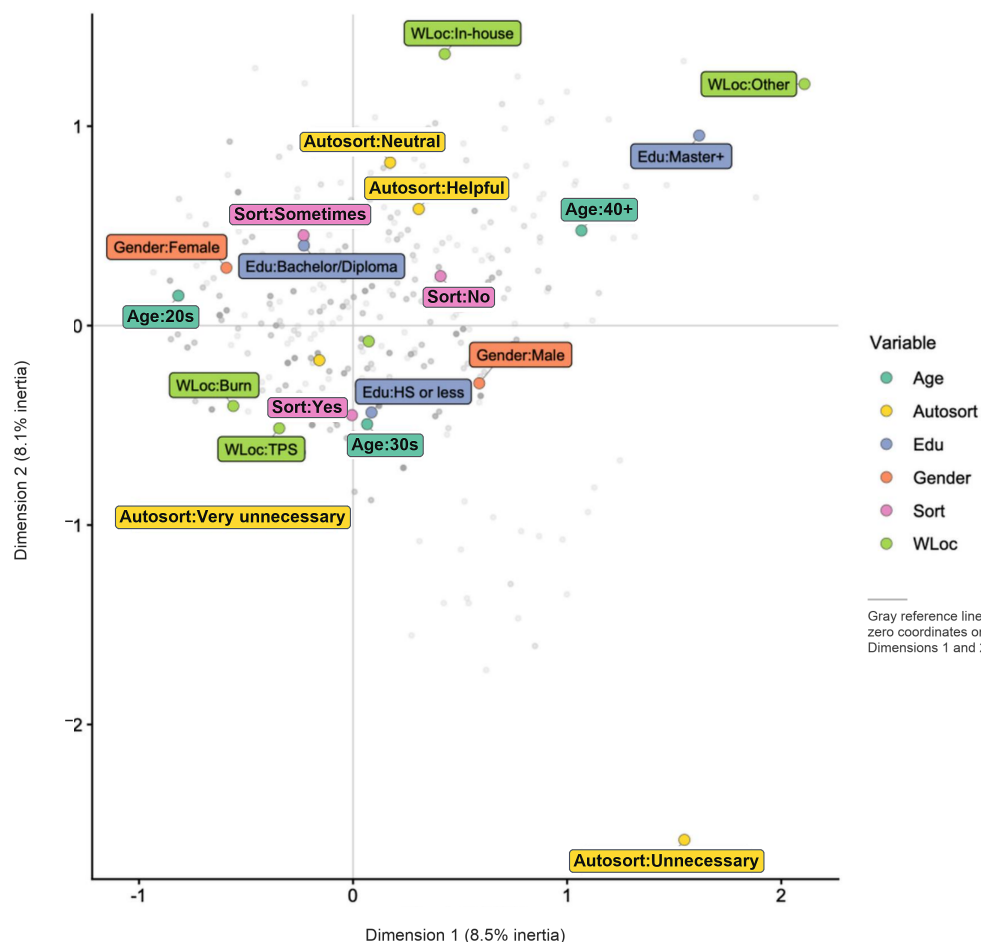


Figure 2 Multiple correspondence analysis map for Set A. The horizontal and vertical gray lines are zero-reference lines corresponding to Dimension 1 = 0 and Dimension 2 = 0, respectively. The percentages shown in the axis labels indicate the inertia represented by each dimension

More neutral views and lower day-to-day engagement. Older and more highly educated modalities appear to be somewhat closer to neutral rather than strongly positive ratings

of automated sorting. This should not be interpreted as an outright rejection. It suggests a less enthusiastic configuration in which direct involvement in routine household waste handling may be weaker or more delegated.

Male-coded and less engaged modalities. Male modalities appear to be somewhat closer to lower sorting engagement, which is consistent with household studies in which waste handling is often unevenly distributed within the home. The MCA result is interpretive and descriptive rather than a respondent classification.

Less favorable responses remained peripheral and sparse. The least favorable Autosort category remained sparse and appeared on the MCA space periphery. This reinforces the decision to cautiously interpret the map and not to build strong substantive claims around tiny negative categories.

3.2.3 MCA plot output of set B: household characteristics and service perception

Figure 3 illustrates associations among household structure, perceived service reliability, waste-management behavior, and attitudes toward automation.

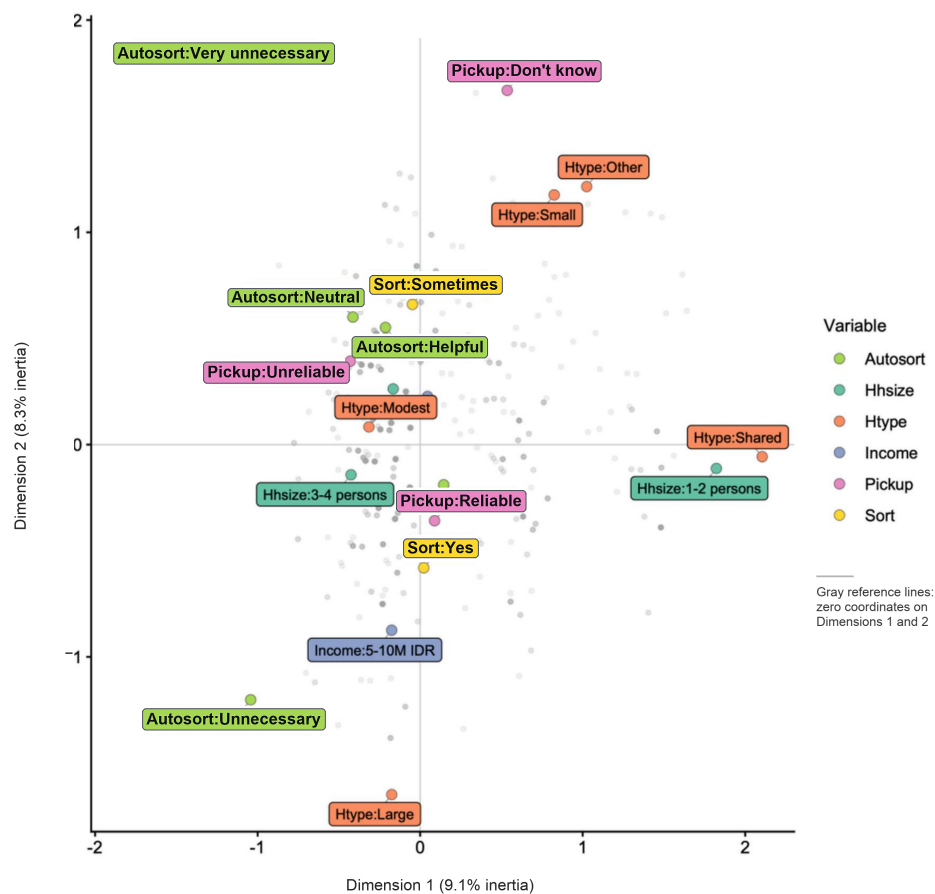


Figure 3 Multiple correspondence analysis map for Set B. The horizontal and vertical gray lines are zero-reference lines corresponding to Dimension 1 = 0 and Dimension 2 = 0, respectively. The percentages shown in the axis labels indicate the inertia represented by each dimension

Most categories lie near the center of the MCA space, indicating overlapping behavioral patterns across household characteristics. Medium household size, more routine sorting, and reliable pickup appear closer to favorable views of automation. However, these relationships should be read as exploratory associations among modalities rather than as evidence of a distinct respondent group.

In contrast, unreliable or uncertain pickup-service conditions tend to appear closer to more

neutral views of automated sorting and lower engagement in sorting behavior. This proximity is descriptive and does not establish that service reliability causes these perceptions.

Peripheral modalities also suggest an exploratory association among shared or compact housing environments, more diffuse responsibility for waste sorting, and less direct household participation in separation practices.

3.2.4 Regional disparity in service reliability and waste location in Indonesia

Figure 4 maps reported reliable pickup across the six grouped island-region categories used in the analysis. Reliable pickup was reported by 72.9% of respondents in Java, 71.4% in Kalimantan, 60.3% in Sulawesi-Gorontalo, 57.4% in Bali-NTB-NTT, 56.8% in Sumatra, and 51.5% in Maluku-Papua.

The Sumatra estimate combines the Sumatra fielding group with Kepulauan Bangka Belitung and Kepulauan Riau, which is consistent with the six-category analytical variable used in Tables 1 and 2. This grouping keeps the map aligned with the regional variable used throughout the analysis.

The map is intended for spatial communication rather than geographic inference. Its boundaries delineate only the six analytical island-region groups, and each group is assigned one descriptive value. The figure therefore does not imply province-level representativeness or province-specific estimates.

At the grouped level, the descriptive contrast indicates more favorable pickup reliability in Java and Kalimantan and less favorable conditions in Maluku-Papua. These patterns provide service-context information for interpreting perceptions of automated sorting; however, they should not be read causally or as direct evidence of implementation readiness.

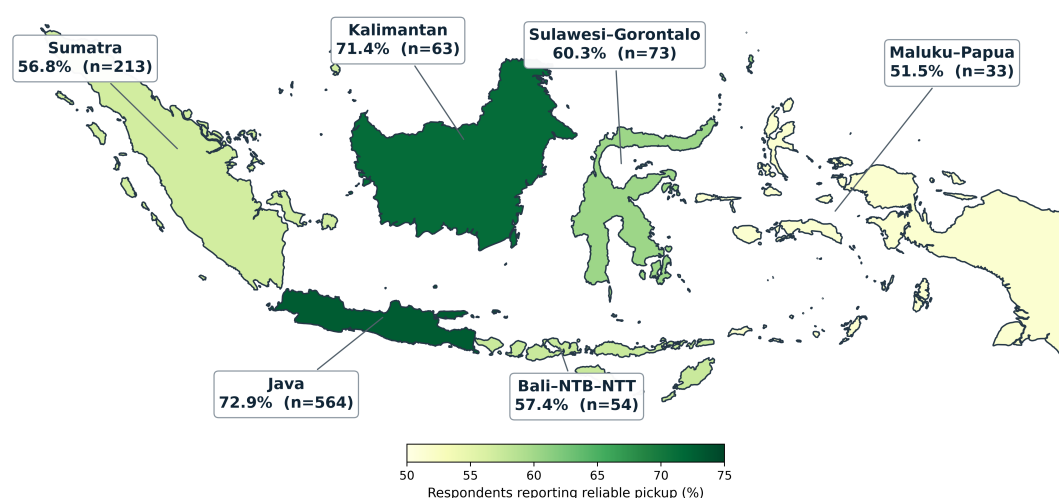


Figure 4 The map presents results for the six grouped island regions. Province boundaries are shown only for geographical orientation and do not represent province-level estimates

3.2.5 Interpretive summary of the recurring modality patterns

Across the three MCA maps, several recurring modality associations emerge without treating them as respondent classifications. Favorable views of automated sorting tend to appear closer to younger age groups, more active sorting behavior, and more reliable pickup contexts. More neutral views tend to appear closer to configurations in which day-to-day waste handling is less central or less engaged within the household, whereas weaker or more uncertain service conditions tend to appear closer to less favorable or less enthusiastic views of waste-related automation.

3.3 Chi-square Test and Cramer's V Results

Table 4 presents the selected chi-square associations among key analytical variables, together with Cramer's V and expected-cell diagnostics. These tests are used here as exploratory follow-up checks rather than as confirmatory models.

The largest association in the reported set linked waste disposal or storage location with pickup-service reliability (Cramer's $V = 0.248$), whereas grouped region, age, income, and self-reported sorting behavior showed weaker but still statistically nonrandom relationships with service reliability or perceived helpfulness.

Overall, the inferential results support a cautious interpretation: several relationships are statistically meaningful, but most effect sizes remain weak to moderate and should be read as exploratory evidence rather than as strong explanatory relationships. The Region $\times$ Opickup result should be interpreted cautiously because 19.0% of expected cells were below five, close to the conventional 20% rule-of-thumb threshold for chi-square reliability.

Table 4 Reported chi-square associations among the key analytical variables

Variable 1	Variable 2	p-value	Cramér's V	Expected cells < 5 (%)
WLoc	Opickup	< 0.001	0.248	13.3
Region	Opickup	< 0.001	0.140	19.0
Age	Autosort	< 0.001	0.116	0.0
Sort	Autosort	0.019	0.087	8.3
Income	Opickup	< 0.001	0.120	0.0
Age	Opickup	< 0.001	0.098	0.0

3.4 Follow-up with Pearson Residual

Pearson residuals were examined for selected contingency tables to extend the interpretation beyond overall statistical significance. Positive residuals indicate overrepresented category combinations relative to independence, whereas negative residuals indicate underrepresented combinations.

Figure 5 presents the Pearson residual heatmaps for the selected pairs, and Table 5 summarizes the most substantively relevant overrepresented or underrepresented combinations. The clearest residual contrast appears in the relationship between waste location and pickup reliability, where open-space disposal is strongly overrepresented when unreliable pickup is reported. Taken together, the residual results reinforce a simple point: less favorable service environments and less enthusiastic perceptions of automation tend to co-occur, but the specific pattern differs across household, age, and regional contexts.

4. Discussion

The findings suggest that public receptivity to automated waste sorting in Indonesia is linked not only to attitudes toward technology but also to the quality of ordinary waste services. In the abstract, respondents in this online quota-based sample were generally positive toward automated sorting, but the intensity of that positivity varied by age, sorting experience, and pickup-service reliability. Therefore, high headline approval should not be read as equivalent to demonstrated readiness for implementation.

This interpretation is broadly consistent with international evidence. Studies from Europe and East Asia have shown that when these technologies are embedded in reliable collection routines and supported by clear feedback, residents are more likely to engage with smart bins, pay-as-you-throw systems, and digital environmental services (Liu & Hsu, 2022; Shan et al., 2024). Conversely, research from lower-income and institutionally uneven settings often finds

that weak infrastructure and uncertain service delivery constrain the practical appeal of otherwise promising waste technologies (Ferronato et al., 2024; Melese et al., 2025; Tan & Taeihagh, 2020). The Indonesian pattern observed here is more consistent with the latter literature: receptivity is present, but it appears conditional on the credibility and workability of the surrounding service system.

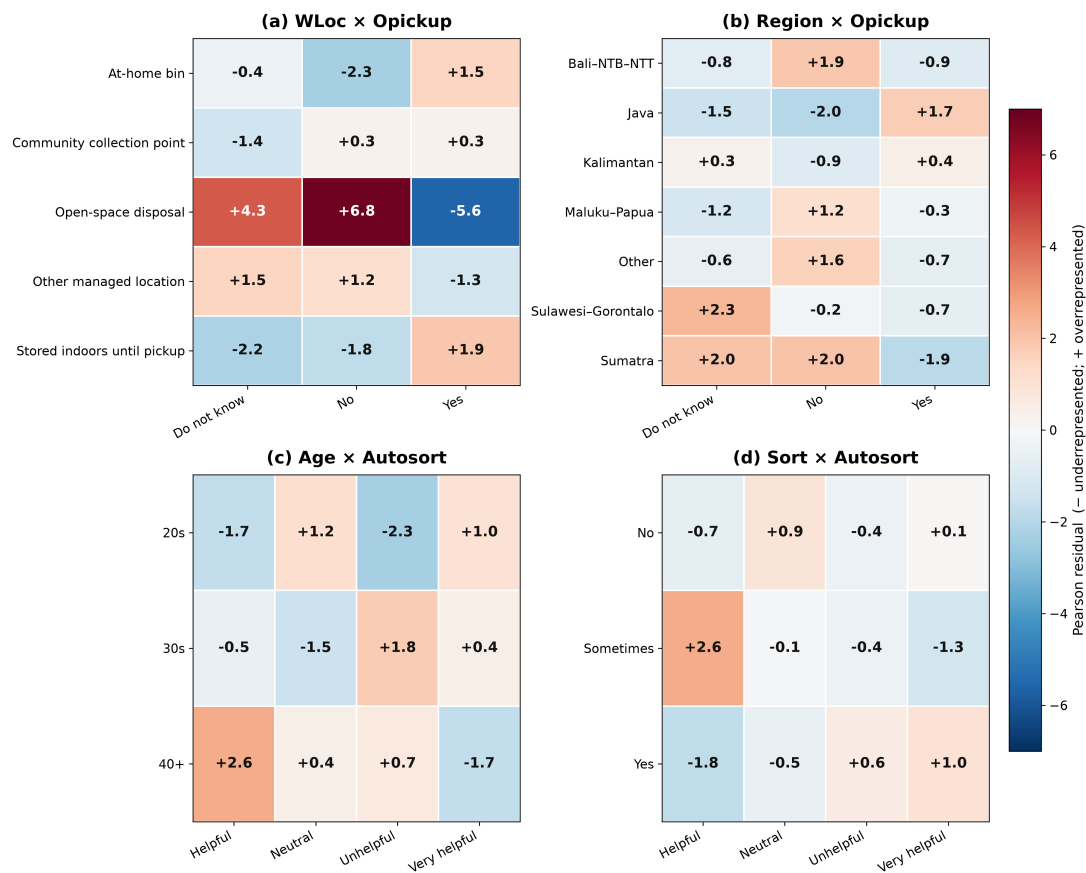


Figure 5 Pearson residual heatmaps for selected contingency tables: (a) waste disposal or storage location (WLoc) × pickup-service reliability (Opickup); (b) island-region group (Region) × pickup-service reliability (Opickup); (c) age group (Age) × perceived helpfulness of automated waste sorting (Autosort); and (d) waste-sorting behavior (Sort) × perceived helpfulness of automated waste sorting (Autosort). Positive residuals shown in red indicate category combinations that are overrepresented relative to independence, whereas negative residuals shown in blue indicate underrepresented combinations. Larger absolute residuals indicate stronger departures from independence

Community-based initiatives such as waste banks remain relevant in this context because they can connect environmental behavior with visible everyday routines and small-scale incentives (Asteria & Herdiansyah, 2022; Budiarto et al., 2025). Instead of assuming that automation alone will change behavior, the results point toward combinations of service improvement, communication, and locally workable implementation pathways.

4.1 Technical and Program Implications

Because receptivity varies across age groups and service contexts, waste management technologies should be designed to be low-burden, legible, and compatible with existing household routines. The results suggest that service reliability and everyday usability may matter as much as novelty when people evaluate automation-related interventions.

Table 5 Selected high-magnitude Pearson residual patterns from the contingency analysis

Variable pair	Residual pattern	Interpretation
WLoc $\times$ Opickup	Open-space disposal + No ($r = +6.76$); Open-space disposal + Yes ($r = -5.64$)	Open disposal was concentrated where pickup was less reliable
Region $\times$ Opickup	Sulawesi-Gorontalo + Do not know ($r = +2.28$); Sumatra + No ($r = +2.05$)	Regional differences mainly reflect uneven service predictability
Age $\times$ Autosort	Age 40+ + Helpful ($r = +2.62$); 20s + Unhelpful ($r = -2.32$)	Older respondents were less enthusiastic and did not strongly reject
Sort $\times$ Autosort	Sometimes + Helpful ($r = +2.61$)	Sorting familiarity was associated with receptivity, but the contrast remained moderate

Pilot studies may be more feasible for evaluating whether app-based feedback, sorting support, or collection-related automation is actually used as intended in better-served settings once basic collection routines are already reliable. Improvements in collection regularity and waste handling may need to precede or accompany any digital deployment in less reliable service environments.

4.2 Policy Implications

The findings also support a more differentiated policy interpretation. Because grouped regional results reflect uneven service conditions, policy responses should be tailored and tested rather than being assumed to scale uniformly across all settings. The results are more consistent with a sequencing logic for piloting than with a fixed province-by-province prescription.

Gendered patterns in sorting behavior remain relevant, but they should be interpreted cautiously because the survey did not directly measure household decision processes. Even so, outreach through community networks such as PKK and through locally trusted service channels may be useful where waste sorting already depends heavily on household routines.

Local governments and service providers may need to prioritize predictable pickup schedules, transparent communication, and practical alternatives to open disposal if they want automated or digital waste systems to be viewed as genuinely helpful rather than as disconnected technical add-ons.

Several limitations should be acknowledged. First, the survey was conducted online, which may underrepresent groups with weaker Internet access or lower digital literacy. Second, the key outcome is an anticipatory perception measure rather than observed use because automated sorting is not yet widely deployed in Indonesia. Third, the study relies on self-reported behavior and cross-sectional associations; therefore, common-method bias, residual confounding, and temporal ambiguity remain possible. Fourth, several variables were grouped into broader categories to support stable interpretation, which improves analytical coherence but reduces geographic and behavioral granularity. For transparency, this article also uses the same underlying survey dataset as our earlier conference paper (Pandyaswargo et al., 2025), while making a different analytical contribution focused specifically on the perceived helpfulness of automated sorting under uneven service conditions.

5. Conclusion

This study used a quota-based online survey of 1,000 adults to examine the perceived helpfulness of automated waste-sorting technology in Indonesia and an exploratory analytical framework combining descriptive statistics, MCA, chi-square tests, Cramer's V, and Pearson residual analysis. Three broad findings emerge. First, the perceived helpfulness of automated

sorting was generally high in this online sample, especially among younger respondents and those already engaged in waste sorting. Second, weaker or uncertain pickup-service conditions were associated with less favorable or less enthusiastic views of automated sorting. Third, perceptions of smart waste technologies appear to be linked not only to attitudes toward technology but also to the everyday service environments in which such technologies would be introduced. These findings should be interpreted as exploratory evidence rather than as nationally representative or causal results. Even so, they suggest a practical implication: strengthening routine service reliability may be as important as the technology design itself in underserved settings, whereas evaluating automation through carefully designed pilots may be more realistic in better-served settings. Once smart waste systems are actually piloted, future research should compare stated perceptions with observed use, examine more geographically detailed service conditions, and test whether similar patterns of conditional receptivity appear in other emerging-economy settings.

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Conflict of Interest

The authors declare no conflicts of interest.

Declaration of AI

During the preparation of this work, the authors used ChatGPT (OpenAI, San Francisco, USA) to improve language clarity, sentence structure, and consistency in the manuscript text, and to assist in drafting the non-data-based graphical abstract. After using this tool, the authors reviewed and edited all outputs as needed and take full responsibility for the content of the published article.

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