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Research on households' willingness to pay for the options of price calculation of household solid waste management services in Hanoi

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Abstract:

This study used the contingent valuation method (CVM) to investigate and analyse the current status of household solid waste management and evaluate people's consensus and willingness to pay (WTP) for household solid waste collection, transportation, and treatment services among urban, rural, and mountainous areas in Hanoi. It also utilised regression analysis to assess factors affecting people's WTP. The study surveyed a sample size of 405 households. To ensure a basis for comparison among urban, rural, and mountainous areas, the study distributed and conducted an equal number of 135 surveys in each area through random sampling. The research results indicate that the average household solid waste in Hanoi is highest in urban areas at 1.27 kg/household/day, followed by rural areas at 1.21 kg/household/day, and mountainous areas at 1.067 kg/household/day. However, most household solid waste has not been classified at the source. Regarding WTP for household solid waste collection, transportation, and treatment services, the results show that 85% of urban households agreed to pay higher than the proposed price, with an average WTP of 1,136 VND/kg. In rural households, 47% agreed to pay 778.96 VND/kg, and 11% of mountainous households agreed to pay an average of 673.04 VND/kg. These insights can guide tailored waste management pricing strategies across diverse urban and rural settings.

Keywords: **contingent valuation method, Hanoi, household solid waste, solid waste management, willingness to pay.**

Classification number: **5.3**

1. Introduction

Solid waste management is a major environmental problem in Vietnam [1]. According to a World Bank report, the amount of household solid waste generated by Vietnamese people is estimated to be 1.14 kg/person/day, higher than the average of other middle-income countries at 0.79 kg [2].

Globally, many countries have practical policies for managing, collecting, and treating solid waste. They have introduced various measures and regulations to encourage compliance, increase recycling rates by classifying waste at the source, and apply modern waste treatment and recycling technologies. Intentional violations are severely punished. To reduce the financial burden on residents, many governments subsidise waste collection companies.

Amornchai Challcharoenwattana and Chanathip Pharino, in a report on urban waste management in Thumbon Phang Khon, Sakon Nakorn Province, Thailand, describe a voluntary waste collection service operated by a government agency, collecting municipal fees of 1.95 USD (1 USD = 30.73 Thai Baht) per household per year for daily waste collection. Additionally, the landfill charges 16.27 USD/ton for municipal waste from operating agencies and 32.54 USD/ton from private units. The research shows that community-based urban waste management reduces greenhouse gas emissions and landfill costs by about 7.41 USD/ton of urban waste, potentially reducing costs to 6.55 USD/ton according to estimated scenarios. This study provides important lessons and demonstrates that urban waste reduction through community activities can be scaled up and implemented in approximately 50% of communities in Thailand and Southeast Asia, where populations still reside in rural or peri-urban areas [3].

M.D.M. Samsudina's 2013 publication on municipal solid waste management in Malaysia describes the country's situation, estimating that Malaysia generated about 5,475 million tons of municipal solid waste in 2001, equivalent to 0.81-1.7 kg/person/day [4]. The most common method is landfilling, primarily using public landfills due to its low cost, posing significant challenges for solid waste management with relatively poor management levels and a lack of organisation. The average solid waste management fee in Malaysia is only about 0.06 RM (~311.09 VND) per kg of waste, equivalent to about 1.2 USD/ton (~27,600 VND/ton). Compared to other developing countries, this fee is much lower, such as Argentina and Brazil, where fees range from 5-18 USD/ton (~115,000-414,000 VND/ton); Chile (5-17 USD/ton ~115,000-391,000/ton); Mexico (4-17 USD/ton~92,000-391,000 VND/ton); South Africa (12 USD/ton~276,000 VND/ton); Hong Kong (10 USD/ton~230,000 VND/ton); and equivalent to countries in the region such as Indonesia (1.3 USD/ton~30,000 VND/ton) and China (2.5 USD/ton~57,500 VND/ton). Given these low fees, Malaysia's solid waste management charges need careful consideration to ensure the necessary resources for solid waste management can be secured and sustained.

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Currently, the Vietnam's Environmental Protection Law 2020 has introduced many new provisions related to household solid waste management. A fundamental change is the shift in regulations on payment for household solid waste collection, transportation, and treatment services from state subsidies to self-paying entities. Clause 1, Article 79, stipulates that the price of household waste management services should be calculated based on the mass or volume of classified waste, including recyclable and reusable waste, and hazardous waste. It requires classification of household solid waste at the source into three categories: recyclable solid waste, food waste, and other common household solid waste [5]. The Vietnam Ministry of Natural Resources and Environment will provide guidance on pricing methods for household solid waste management services, establish economic and technical norms for the collection, transportation, and treatment of municipal solid waste, and offer technical guidance on household solid waste classification. Regulations on collecting fees for household solid waste management will be implemented from 2025 [6, 7]. For these regulations to be effectively implemented, public understanding and cooperation with the Government are essential.

Hanoi, as a metropolitan area and the centre of economic, political, cultural, technological, and educational activities in Vietnam, faces increasing domestic waste due to rapid economic development, high living standards, and high consumption. This growth places significant pressure on the collection, transportation, and treatment of waste. On average, Hanoi generates about 6,500 tons of household solid waste daily. Most urban solid waste has not been classified at the source, as classification is not mandatory. The collection rate of household solid waste in inner-city areas is about 95%, while it is 66% in suburban areas [2]. However, different types of waste are often mixed and transported to treatment sites, where 89% of household solid waste is treated by landfilling and 11% by incineration [2]. The management of household solid waste, from classification and collection to transportation and treatment, remains outdated, posing significant environmental pollution risks and public health concerns [1].

Research in Vietnam has primarily focused on the theoretical basis and general models of household solid waste management, along with the current situation related to municipal solid waste. Few studies have examined factors influencing the implementation of solid waste analysis, collection, and transportation, or the WTP among urban, rural, and mountainous populations for household solid waste services. This study aims to fill this research gap by analysing and evaluating the differences in WTP among communities in Hanoi.

To assess the readiness to implement the new regulations of the Vietnam Environmental Protection Law 2020 regarding household solid waste management pricing based on classified mass or volume, and to understand how socio-economic status influences WTP across different urban, rural, and mountainous communities within Hanoi, this study was conducted. The findings are crucial for stakeholders, including policymakers, urban planners, and the community, to develop more effective and equitable waste management policies that can improve compliance rates and sustainability.

2. Methodology

2.1. Data sources and collection

2.1.1. Secondary data sources and collection methods

The collected data include socio-economic conditions, census reports, documents and reports from the Hanoi Department of Natural Resources and Environment, District Department of Natural Resources and Environment, current legal documents related to household solid waste management, and reports from the Environment and Urban Environment Limited Company (URENCO) with data on household solid waste management and treatment planning in Hanoi [8]. Published papers in journals related to the research subject, including studies on WTP using the CVM random assessment method [9-13], and published papers on people's WTP and pricing plans for solid waste management services in Vietnam [14-17], were also reviewed.

2.1.2. Primary data sources and collection methods

Primary data were collected through a questionnaire survey to gather information about the current status of household solid waste management. The study conducted online and face-to-face interviews with household heads or income earners in households in Hanoi.

2.2. Method for forecasting the amount of household solid waste generated by 2030

To forecast the amount of household solid waste generated in Hanoi by 2030, the study is based on the improved Euler model. The improved Euler formula (Eq. 1) is a mathematical formula used to forecast population, expressed as follows [14]:

$$N^*_{i+1} = N_i + r \times N_i \times \Delta t \quad (1)$$

where, N^*_{i+1}: population after one year (people); N_i: initial population (people); r: population growth rate (%/year); Δt: time (year).

From the results of the projected population over the years calculated, the average amount of waste generated in the following years is calculated according to the formula (Eq. 2) [14]:

$$X_{i+1} = X_i + n \times X_i \quad (2)$$

where X_{i+1}: the average amount of waste generated in year i+1; X_i: the average amount of waste generated in year i; n: rate of increase in discharge rate (%).

2.3. Contingent valuation method

To estimate people's WTP to implement a plan to calculate the price of household solid waste management services based on the mass or volume of classified waste, the study followed the steps of the CVM. CVM essentially provides values (in terms of WT) or willingness to accept compensation - WTA) of the concerned people for an environmental good as stated by them during a survey. WTP and WTA are used because many of the project impacts to be included in the economic analysis will be unmarketable, such as biodiversity preservation, or incompletely marketed, such as water supply and sanitation benefits.

The steps to conduct specific research are as follows:

2.3.1. Set up investigations and interviews

Purpose: To collect information about the socio-economic characteristics of the interviewee's household, activities generating household solid waste, waste composition, and the WTP for implementing the plan to calculate the price of household solid waste management services based on the mass or volume of classified waste in Hanoi.

Structure of the survey form: i) Set up questions to collect information related to the current status of waste classification and management in household activities; ii) Develop a scenario and set up questions to collect information about people's WTP to implement a plan to calculate the price of household solid waste management services based on the mass or volume of classified waste in Hanoi; iii) Collect general information such as full name, year of birth, gender, address, phone number, ID card, education level, occupation, average income, number of people in the household, and area of the house.

2.3.2. Conduct interviews with a specified number of samples

The survey sample size is calculated according to the following formula [18]:

$$n = \frac{N}{1 + Ne^2} \quad (3)$$

where, *n*: is the sample size; *N*: is the total number of households in the study area; *e*: is the standard error (this study chooses *e*=0.05).

According to the 2020 statistical yearbook, the total number of households in Hanoi was 2,224,107. From this value, the following sample size is calculated as:

$$n = \frac{2{,}224{,}107}{1 + 2{,}224{,}107 \times 0.05^2} \approx 400$$

Thus, the study was conducted with a sample size of 405 questionnaires. To form a basis for comparison between the research areas (urban, rural, and mountainous), the study distributed and conducted 135 surveys in each of the three areas using random sampling.

Before the official investigation, the research team conducted a pilot survey of 20 questionnaires to adjust the script and questionnaire accordingly. In the pilot survey, prices were given in the form of open-ended questions, and respondents indicated the price they were willing to pay. The results from the trial survey obtained three price levels: 650, 900, and 1,500 VND/kg. This formed the basis for including prices in the official questionnaire according to the double-bounded random survey model.

In the official survey, the research team used valuation questions in the form of an auction and conducted the survey according to the double-bounded random survey model. The iterative randomised survey model is depicted in Fig. 1 [19].

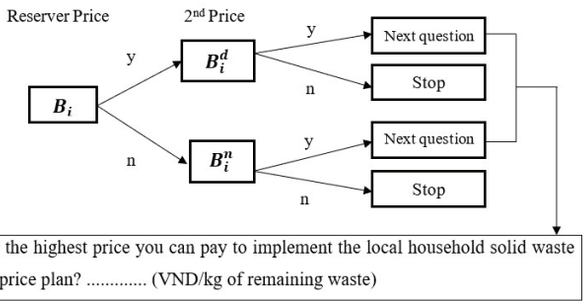

Fig. 1. The double-bounded model.

According to the double-bounded survey model, the interviewee will be asked, "Do you agree with the starting WTP price?" In this study, the starting price is taken from the average WTP price of several people in the trial survey form. If people answer "yes," it means they can pay a higher price, and they will continue to be asked their WTP a higher price until they find the highest WTP. If the person answers "no," it means they will only pay the lower price, and they will be asked the lower price, then asked about their highest WTP. This is the basis for choosing the appropriate price in the iterative double-bounded survey model.

2.4. Data processing methods

Microsoft Excel was used to perform calculations with encrypted data from the questionnaire after the interviews were completed.

- Interview results were analysed using the descriptive statistics tool in Excel to conduct statistics and calculate the average WTP.

- The total WTP was calculated in the following manner:

TWTP of all households = Average WTP × Total population of Hanoi × % of people WTP

The WTP level varies due to a wide dependence on many factors such as income, education level, age, gender, and household average monthly water volume use. Thus, the WTP function has the following form:

$WTP_i = \beta_0 + \beta_1$ (Income) + β_2 (Education) + β_3 (Gender) + β_4 (Age) + β_5 (Members) + β_6 (D) + β_7 (K) [14]

where WTP: willingness to pay (VND); β_0: intercept; β_1, β_2, β_3, β_4, β_5, β_6, β_7: coefficients.

The coefficients are explained as follows:

Income: The study employs a correlation model using pseudo-variables for the income variable coded as follows:

- Equal to 1 if less than 5 million VND/month.
- Equal to 2 for 5-10 million VND/month.
- Equal to 3 for 10-15 million VND/month.
- Equal to 4 for 15-20 million VND/month.
- Equal to 5 for 20-25 million VND/month.
- Equal to 6 for 25-30 million VND/month.
- Equal to 7 for 30-35 million VND/month.
- Equal to 8 for over 35 million VND/month.

Education: The study uses dummy variables for the education level variable coded as follows:

- Degree 0: no degree.
- Degree 12: high school.
- Degree 16: university/college/intermediate.
- Degree 18: post-graduate.

Gender: The study uses dummy variables for gender coded as follows:

- Equal to 1 for male.
- Equal to 0 for female.

Age: The study uses dummy variables for age coded as follows:

- Equal to 1 for under 18 years old.
- Equal to 2 for 18-24 years old.
- Equal to 3 for 24-55 years old.
- Equal to 4 for over 55 years old.

Members: Number of people in household.

Jobs (D): The study uses dummy variables for jobs coded as follows:

- Equal to 1 for civil servants.
- Equal to 2 for free business.
- Equal to 3 for students.
- Equal to 4 for workers.
- Equal to 5 for housewives/retirees.
- Equal to 6 for other professions.

Volume of household solid waste (K): Volume of household solid waste in kg/day/household.

3. Results and discussion

3.1. Assessing the current status of household solid waste generation and collection in Hanoi

According to the results from a survey of 405 households, the average amount of daily household solid waste is 1.182 kg/household/day. The amount of household solid waste varies across different areas, with urban areas generating the highest rate at 1.27 kg/household/day, followed by rural areas at 1.21 kg/household/day, and mountainous areas at 1.067 kg/household/day. This discrepancy can be attributed to the higher population density and demand for goods and services in urban areas compared to rural and mountainous areas. Additionally, the predominant housing type in urban areas, such as apartment buildings with dense populations, makes recycling household solid waste more challenging than in the other two areas, resulting in a higher per capita waste generation in urban areas.

Comparing the results of the household solid waste volume generation coefficient in urban, rural, and mountainous areas of Hanoi residents (Fig. 2) with data from the 2019 State of the Environment Report shows a smaller coefficient. Specifically, the average generated volume in urban areas is approximately 3 kg/household/day, and in rural and mountainous areas, it is approximately 2.5 kg/household/day. The discrepancies in the survey results may be due to a limited number of sample forms, short survey duration, and infrequent survey repetitions, which could affect accuracy.

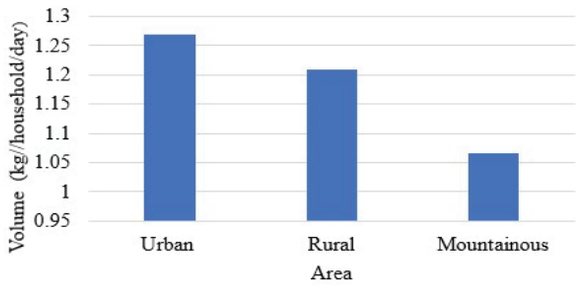

Fig. 2. Household solid waste volume for each study area.

The survey results from 405 households registered for household solid waste collection services revealed that 81.23% of respondents believe the frequency of household solid waste collection is reasonable, while 18.77% consider it unreasonable. Additionally, 83.46% of respondents think the timing of household solid waste collection is reasonable, whereas 16.54% do not. The assessment of collection frequency (81.23%) from the questionnaire is almost similar to the collection results in Hanoi's report on the current state of the environment from 2016-2020 (93%). The discrepancy in the assessment results, particularly in rural and mountainous areas, may be due to the equal distribution of the questionnaire across these three areas.

According to the survey results, 59% of respondents recognise the importance of separating household solid waste before treatment. Most questions on household solid waste pertained to two categories: organic waste and inorganic waste (36% of total questions). However, a significant portion (41%) indicated no classification, with 90% citing the inconvenience of garbage separation as the primary reason. Other reasons include time constraints and the mixing of domestic waste with other types of waste. These findings suggest that respondents in Hanoi are not fully aware of the benefits and drawbacks of not segregating waste at the source. In-depth interviews with URENCO staff revealed that while URENCO complies with standard engineering, shipping, and handling procedures, and possesses modern and sophisticated machinery, equipment, and technology for cleaning and maintenance, domestic solid waste management and public understanding of URENCO's operations vary between urban, rural, and mountainous areas. Urban residents have a better understanding of business operations and benefits from domestic solid waste management than those in rural and mountainous areas. Based on evaluation data, the study proposes measures for effective communication and management of domestic solid waste in Hanoi. Currently, the collection of household solid waste on small roads is not yet mechanised; collection vehicles are often rusted, causing overflow and leakage of wastewater, which creates an unhygienic environment during collection and transportation.

3.2. Forecasting the amount of household solid waste generated in Hanoi by 2030

Based on the population and annual population growth rate of the locality, the study calculated the current amount of household waste and estimated the volume generated by 2030. The forecast

population is calculated according to Eq. 1. According to the Hanoi Socio-Economic Development Plan for the period up to 2025 and the vision to 2030, the forecast population growth rate from 2025 to 2030 is 2.2%.

According to the Hanoi City Socio-Economic Development Plan for the period up to 2025 and vision to 2030, the forecast population growth rate from 2025 to 2030 is 2.2%.

According to statistics from the General Department of Environment (2014), the rate of solid waste generation in the Red River Delta region is 10% per year. Based on the 2019 environmental status report, the average amount of waste generated per person in Hanoi is 0.81 kg/person/day. The household solid waste collection efficiency is 93%. The results of calculating the amount of household solid waste generated over the years are presented in Table 1.

Table 1. Household solid waste generated in Hanoi by 2030.

Year	Population growth rate (%)	Population (thousands of people)	Average amount of household solid waste generated (kg/person/day)	Average amount of household solid waste generated (tons/day)	Volume of household solid waste collected and treated (tons/day)
2020	2.2	8,230.2	0.89	7,333.1	6,819.76
2021	2.2	8,411.2	0.98	8,243.8	7,666.78
2022	2.2	8,596.3	1.08	9,267.7	8,618.99
2023	2.2	8,785.4	1.19	10,418.8	9,689.47
2024	2.2	8,978.7	1.30	11,712.8	10,892.90
2025	2.2	9,176.2	1.43	13,167.5	12,245.80
2026	2.2	9,378.1	1.58	14,802.9	13,766.73
2027	2.2	9,584.4	1.74	16,641.5	15,476.56
2028	2.2	9,795.3	1.91	18,708.3	17,398.74
2029	2.2	10,010.8	2.10	21,031.9	19,559.67
2030	2.2	10,231.0	2.31	23,644.1	21,988.98

Source: Compiled by the authors.

It is forecasted that the amount of household solid waste generated will be 13,167.5 tons/day by 2025 and 23,644.1 tons/day by 2030. The increasing volume of household solid waste necessitates improvements in the current system of collection, transportation, and treatment to meet future requirements.

3.3. Evaluating willingness to pay for implementing a solution and calculating prices for household solid waste collection, transportation, and treatment services in Hanoi

The results in Table 2 show that, of the 405 surveyed households, there are 218 male heads (54%) and 187 female heads (46%). Thus, the gender disparity among the respondents is not significant.

The majority of interviewees in Hanoi belong to the 18-24 age group, indicating that most respondents are of appropriate school age and possess knowledge of environmental protection, thus providing reliable answers. Additionally, the diversity in age groups allows for an equitable assessment of payment levels.

Table 2. Characteristics of the interviewees.

Characteristics of the subject	Rate
Gender	Male (54%), Female (46%)
Ages	Under 18 age (2.0%), from 18-24 age (55.1%), from 24-55 age (38.5%), over 55 age (4.4%)
Educations	No degree (1%), secondary (15%), university/college/intermediate (68%), Postgraduate (16%).
Jobs	Students (52%), officer/civil servant (13%), freelance business (24%), worker (6%), housewife/retired (3%), other (2%)
Members	One person (4.2%), two people (18.8%), three people (12.8%), four people (35.8%), five people (14.6%), six people (6.9%), seven people (5.9%), eight people (1%)
Income	Under 5 million VND/month (19%), 5-10 million VND/month (19%), 10-15 million VND/month (21%), 15-20 million VND/month (11%), 20-25 million VND/month (4%), 25-30 million VND/month (4%), 30-35 million VND/month (7%), >35 million VND/month (15%)

Source: Compiled by the authors.

The average number of people per household is 3.87. Households with four members constitute the highest rate (35.8%), while those with eight members constitute the lowest rate (1%). Most households have 3-5 members, affecting the volume of household solid waste generation.

Regarding education level, 15% of the households have secondary education, 68% have university/college/intermediate degrees, and 16% have postgraduate degrees. Thus, the education level of the household heads is predominantly at the university/college/intermediate level or higher. The high education level is likely a key factor influencing people's actions and perceptions of the environment, as well as their WTP.

In terms of occupation, the industry is relatively diverse. Students represent the largest proportion (52%), followed by self-employed individuals (24%), and civil servants (13%). The proportion of people working in non-state occupations (workers, traders, other professions) is about three times higher than those in the public sector. The high percentage of students indicates a strength in making informed and reasonable choices due to their knowledge and learning.

Income distribution among the respondents shows that 21% have incomes in the range of 10-15 million VND/month, primarily state employees. Incomes below 5 million and from 5 to 10 million VND/month account for 19% each (students, workers, and other professions). Incomes over 35 million VND/month, mainly from business and trading, account for 15%. Thus, the interviewees' income is generally average or higher, with a higher percentage of middle-income households or above. This higher income correlates with a greater WTP for improved sanitation services, reflecting the household's conditions.

Table 3. Descriptive statistics of WTP for domestic solid waste collection, transportation, and treatment services based on the volume or waste classification in Hanoi.

Target	Unit	$WTP_{urban\ area\ average}$	$WTP_{rural\ area\ average}$	$WTP_{mountainous\ areas\ average}$
Mean	VND/kg	1,136	778.96	673.04
Standard error		30.19	12.40	10.70
Median	VND	930	650	650
Mode	VND	1,500	650	650
Minimum	VND	650	500	300
Maximum	VND	1,500	1000	1,500
Sum	VND	153,360	105,160	90,860
Count		135	135	135

The results in Table 3 show the average WTP of different households in each area:

Households in urban areas have an average WTP of 1,136 VND/kg. The study shows that 85% of households are willing to pay a price higher than the proposed price of 930 VND/kg, while 15% are not.

Households in rural areas have an average WTP of 778.96 VND/kg. The study shows that 47% of households are willing to pay a price higher than the proposed price of 930 VND/kg, while 53% are not.

Households in mountainous areas have an average WTP of 673.04 VND/kg. The study shows that 11% of households are willing to pay a price higher than the proposed price of 930 VND/kg, while 89% are not.

3.4. Analysing factors affecting and comparing willingness to pay in the three research areas

Regression analysis was conducted using Microsoft Excel to identify factors affecting WTP, with independent variables including age, gender, demographics, occupation, education level, income, and the amount of household solid waste generated. The results of the regression model are shown in Table 4.

The regression equation is given for each area below.

For households in urban areas:

$WTP_{urban\ areas}$ = 237.5Constant + 122.64Income + 6.66Education + 44.67Gender - 20.22Age - 13.33Members + 33.76D + 66.99K

The analysis results show that the multiple correlation coefficient (Multiple R) is approximately 0.769, indicating that the selected linear regression model is very suitable. R-Square=0.591 means that the independent variables in the model (income, education, gender, age, demographics, jobs, and the amount of domestic solid waste) explain about 59.5% of the volatility of Y (WTP). About 40.9% is due to random factors and other factors not included in the model (online survey factor).

Table 4. Regression results of willingness to pay dependent variable of surveyed households.

Targets	$WTP_{urban\ areas}$		$WTP_{rural\ areas}$		$WTP_{mountainous\ areas}$	
	Coefficients	*p-value*	*Coefficients*	*p-value*	*Coefficients*	*p-value*
Constant	237.50	0.169	611.39	4.00694E-07	560.01	1.19001E-07
Income	122.64	2.3598E-21	58.61	1.6264E-08	57.26	1.21422E-10
Education	6.66	0.325	5.17	0.151	4.75	0.231
Gender	44.67	0.274	-10.27	0.614	-3.80	0.836
Age	-20.22	0.554	25.55	0.171	5.03	0.814
Members	-13.33	0.371	8.15	0.349	-4.60	0.521
D (occupation)	33.76	0.061	1.76	0.864	-8.25	0.560
K (volume of domestic solid waste)	66.99	0.041	27.26	0.031	23.80	0.034

For households in rural areas:

$WTP_{rural\ areas}$ = 611.39Constant + 58.61Income + 5.17Education - 10.27Gender + 25.55Age + 8.15Members + 1.76D + 27.26K

The analysis results showed that the multiple correlation coefficient (Multiple R) is approximately 0.639, indicating that the selected linear regression model is very suitable. R-Square=0.508 means that the independent variables in the model (income, education, gender, age, demographics, jobs, and the amount of domestic solid waste) explain about 50.8% of the volatility of Y (WTP). About 49.2% is due to random factors and other factors not included in the model (online survey factor).

For households in mountainous areas:

$WTP_{mountainous\ areas}$ = 560.01Constant + 57.26Income + 4.75Education - 3.80Gender + 5.03Age - 4.6Members - 8.25D + 23.8K

The analysis results showed that the multiple correlation coefficient (Multiple R) is approximately 0.614, indicating that the selected linear regression model is very suitable. R-Square=0.477 means that the independent variables in the model (income, education, gender, age, demographics, jobs, and the amount of domestic solid waste) explain about 47.7% of the volatility of Y (WTP). About 52.3% is due to random factors and other factors not included in the model (online survey factor).

Observation of the model showed that the variables of income and the volume of domestic solid waste are directly proportional to the WTP, while the remaining variables have varying relationships with WTP depending on the area.

Firstly, the higher the income, the higher the WTP. When other variables are constant, if the income in urban areas increases by 1 unit, the WTP increases by 122.64 VND. Calculation results: p-value for urban areas (2.3598E-21)<0.05 shows that the income variable has a close relationship with the WTP variable.

When other variables are constant, if the income in rural areas increases by 1 unit, the WTP increases by 58.61 VND. Calculation results: P-value for rural areas (1.6264E-08)<0.05 shows that the income variable has a close relationship with the WTP variable.

When other variables are constant, if the income in rural areas increases by 1 unit, the WTP increases by 58.61 VND. Calculation results: p-value for rural areas (1.6264E-08)<0.05 shows that income variable has a close relationship with WTP variable.

When other variables are constant, if the income in mountainous areas increases by 1 unit, the WTP increases by 57.26 VND. Calculation results: p-value for mountainous areas (1.21422E-10)<0.05 shows that the income variable has a close relationship with the WTP variable.

Secondly, the greater the amount of household solid waste, the greater the WTP and has important implications in paying waste fees. When other variables are constant, if the amount of household solid waste in urban areas increases by 1 unit, the WTP increases by 66.99 VND. P-value for urban areas (0.041)<0.05 shows that the amount of household solid waste variable has a close relationship with the WTP variable.

When other variables are constant, if the amount of household solid waste in rural areas increases by 1 unit, the WTP increases by 27.26 VND. P-value for rural areas (0.031)<0.05 shows that the amount of household solid waste variable has a close relationship with the WTP variable.

When other variables are constant, if the amount of household solid waste in mountainous areas increases by 1 unit, the WTP increases by 23.80 VND. P-value for mountainous areas (0.034)<0.05 shows that the amount of household solid waste variable has a close relationship with the WTP variable.

Research results show that among the major factors directly affecting the WTP variable for domestic solid waste, the two factors "income" and "the amount of solid waste generated" have the greatest influence. This will be the basis for research to develop appropriate solutions. For example, the city government of Hanoi can implement solutions to improve environmental knowledge and promote the behaviour of classifying domestic waste at the source to help reduce the amount of waste discharged into the environment.

Although there have been many efforts to collect and investigate data on the status of household solid waste, as well as the WTP for household solid waste collection, transportation, and treatment services in Hanoi, the CVM method has several limitations related to the technique of assessing WTP. The process of collecting information still faces many difficulties because people are not familiar with the investigation method and may not understand the questions correctly when hypothetical situations are presented.

3.5. Proposing policy recommendations in household solid waste management in Hanoi

Based on model research results, it is evident that the variables of income and volume of household solid waste generated are directly proportional and closely correlated with the WTP variable. Thus, these findings form the basis for making recommendations. To improve the effectiveness of solid waste management policies in line with the 2020 Environmental Protection Law in Hanoi, the following recommendations are proposed:

Firstly, management agencies need to assess the characteristics of each region in household solid waste management, considering the impact factors. Policymakers should consider costs and financial support, particularly for infrastructure required for classifying household solid waste at source. It is crucial for managers to understand the aspirations and financial capacities of people in each region, allowing for adjustments in policies and flexible service pricing plans tailored to each area. When implementing differential pricing, the management agency should consider the variability in payment capacity across urban, rural, and mountainous areas as revealed by WTP analyses.

Secondly, policies should be established to support low-income households in participating in the solid waste management process. Support measures may include funding for collection, transportation, and waste treatment, as well as providing equipment and tools for waste classification and collection. This helps balance the cost burden and enables low-income households to actively engage in sustainable solid waste management.

Thirdly, public cooperation is essential for the success of waste management policies. Comprehensive public awareness and education campaigns should be conducted to inform residents about the importance of waste management and the specifics of new policies. Local media, schools, and community centres should be utilised for outreach.

Although there have been significant efforts to collect and investigate data on the status of domestic solid waste and the WTP for household solid waste collection, transportation, and treatment services in Hanoi, the CVM method has limitations related to assessing WTP. The information collection process faces challenges as people are not familiar with the investigation method and may not understand the questions correctly when hypothetical situations are presented. The study focuses on certain areas of Hanoi, and due to economic and time constraints, the experimental scale is limited. It is recommended that future studies be conducted on a larger scale and with a larger sample size.

4. Conclusions

The study used the CVM to investigate, compile statistics, and analyse the current status of household solid waste management. It also estimated people's consensus and differences in WTP for household solid waste collection, transportation, and treatment services among urban, rural, and mountainous populations in Hanoi.

Research results showed that the average household solid waste in urban areas is the highest, at 1.27 kg/household/day, followed by rural areas at 1.21 kg/household/day, and mountainous areas at 1.067 kg/household/day. However, most household solid waste has not been classified at source. Eighty-five percent of urban households agreed to pay higher than the proposed price, with an average WTP of 1,136 VND/kg; forty-seven percent of rural households agreed to pay 778.96 VND/kg, and eleven percent of mountainous households agreed to pay an average of 673.04 VND/kg. Among the major factors that directly affect the WTP for domestic solid waste, two factors - income and the amount of solid waste generated - have the greatest influence.

The research results are crucial and can influence policymaking, affect public behaviour, and potentially lead to improvements in environmental, economic, and social sustainability in Hanoi. The study has proposed several well-founded and appropriate solutions for the Hanoi area, as well as specific implementing entities, to increase financial resources, raise community awareness, and improve the quality of household solid waste management services for local residents. These provide a practical basis for developing effective household solid waste management solutions suitable to local conditions.

CRediT author statement

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COMPETING INTERESTS

The authors declare that there is no conflict of interest regarding the publication of this article.

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