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Regional Case Study

Sustainable Management and Community Willingness to Pay for Communal Wastewater Services in Yogyakarta

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Abstract

Domestic wastewater discharge into rivers remains a persistent environmental and public health challenge in rapidly urbanizing regions of developing countries such as China. Although communal wastewater treatment systems have been increasingly implemented, empirical studies integrating community willingness to pay (WTP), behavioral determinants, and sustainability planning are limited. This study analyzes community willingness to pay for communal wastewater treatment services and formulates sustainability-oriented strategies for the Sewon Communal Wastewater Treatment Plant (WWTP) in the Special Region of Yogyakarta, Indonesia. A mixed-methods approach combined a survey of 100 households with interviews and a document analysis. WTP was estimated using the contingent valuation method with a payment card format, while behavioral determinants were examined using covariance-based Structural Equation Modelling (SEM) with AMOS. Strategic formulation was conducted using SWOT analysis supported by IFAS and EFAS matrices based on validated SEM results. The results indicate a positive willingness to pay, with a mean of IDR 7,114 and a median of IDR 7,500. The SEM revealed that supporting institutional factors significantly influenced the WTP ($X4 = 0.664$; $p < 0.01$), whereas environmental perception and inhibiting factors were not statistically significant. These findings highlight the decisive role of institutional strength in ensuring the financial sustainability of the communal wastewater service.

Keywords: Community participation; communal wastewater treatment; domestic waste management; SEM-AMOS; sustainability; willingness to pay

1. Introduction

Domestic waste refers to waste generated by daily human activities, such as bathing, washing, cooking, and using the toilet. This waste includes water from bathrooms, kitchens, and laundry rooms, as well as human waste. If not managed properly, domestic waste can pollute the environment and endanger public health. Domestic waste includes various types of waste produced by households, such as food waste, paper, glass, metal, plastic, and textiles (Gautam *et al.*, 2024). This waste includes organic waste, such as vegetables, fruit peels, bones, meat, fish, and chicken scraps, which are classified as wet waste (Mao *et al.*, 2022). Improper disposal of these wastes can pollute soil, rivers, and groundwater, posing serious threats to human health and the environment (Marleni and Raspati, 2020) and remains a major global environmental challenge in developing countries (Awewomom *et al.*, 2024).

Population growth and urbanization have significantly increased household waste generation, particularly in developing regions, where waste generation is strongly correlated with income and population density (Verma and Reddy, 2025). Similar trends have been reported in recent global assessments (Lozano *et al.* 2023). According to the Ministry of Environment and Forestry (KLHK, 2019), households contribute a substantial portion of national waste, with a large number discharging wastewater directly into rivers or infiltration pits instead of using proper septic systems. Simanjuntak et al. (2024) highlighted that irregular disposal, inadequate infrastructure, and low public awareness cause environmental pollution. Fitriyanti (2020) reported that over 60% of rivers in Indonesia are contaminated by domestic waste, demonstrating the urgent need for an effective waste management system. Priambodo and Herumurti (2020) noted that untreated household wastewater is a major source of waterborne pathogens and chemical pollutants, contributing to waterborne diseases in many regions.

One strategy for managing domestic wastewater is the house connection (HC) system, which channels household wastewater to communal wastewater treatment plants (WWTP) (Marhayuni *et al.*, 2022). In the Sewon District of Yogyakarta, the HC system was initially designed to serve approximately 25,000 households with a treatment capacity of 15,500 m^3/day. The system is planned to expand to 50,000 connections by 2040, requiring significant investments in infrastructure and technical capacity (Priambodo and Herumurti, 2020). However, the management of HC systems faces several technical and institutional challenges, including maintenance issues, occasional blockages, and coordination difficulties between multiple agencies responsible for sewer networks (Sekretariat Bersama Karmantul, 2014; Kinasih, 2015). These issues can reduce the operational efficiency and public trust in the system.

Community participation is essential for ensuring the sustainability of wastewater management services. One approach to measure this is the Willingness to Pay (WTP), which reflects the maximum amount individuals are willing to contribute to environmental benefits and service sustainability (Marselina, 2021). Similar studies in Southeast Asia, such as in Vietnam, show that WTP is closely associated with household income and perceived service quality (Thuy *et al.* 2024). Recent studies have also highlighted the role of institutional trust and governance factors in shaping community payment behavior (Muhdiarta, 2025). WTP is influenced by factors such as income, household size, proximity to treatment facilities, and the perceived quality of services (Priambodo and Herumurti, 2020). Institutional support, government regulations, and community awareness also play crucial roles, as well-structured policies and clear regulations can enhance trust and commitment (Willetts 2020). However, technical limitations, weak coordination among stakeholders, and limited socialization efforts can indirectly reduce WTP by diminishing public confidence in service effectiveness (Azizatun, 2015; Paramita and Koestoer, 2021).

Adopting a circular economy approach can improve the sustainability of communal wastewater management by converting domestic waste into valuable products, such as biogas, liquid fertilizer, or compost, while minimizing environmental impacts (Suhardono *et al.*, 2025). This approach not only reduces waste volume but also promotes community engagement, as residents can directly benefit from the outputs of effective waste management. Effective wastewater management, supported by technology, institutional frameworks, and community participation, can enhance environmental quality and ensure the long-term sustainability of community systems (Rachmawati and Suryani, 2020). Achieving sustainable wastewater management thus requires an integrated socio-economic environmental approach that balances technical solutions with community participation and governance (Hariram *et al.*, 2023).

Therefore, there is a clear study gap in combining proven behavioral factors that influence willingness to pay with existing strategies for planning sanitation initiatives. Few prior studies have integrated the estimation of willingness to pay, structural equation modelling for behavioral analysis, and SWOT-based strategic formulation within a single, sequential framework, particularly focusing on communal wastewater treatment systems in developing countries. Given this background, this study aims to analyze the level of community willingness to pay for domestic wastewater management through the HC system and identify the factors influencing this willingness.

2. Methods

2.1 Study Area

This study was conducted in the Sewon Subdistrict, Bantul Regency, Special Region of Yogyakarta, Indonesia, located at coordinates −7.87639° S and 110.35889° E. As shown in Figure 1, Sewon is a densely populated residential area situated in the southern part of Yogyakarta City that has experienced rapid development in the recent years. This subdistrict was chosen as the research location because it has a domestic wastewater management system utilizing house connections (HC) linked to the Sewon Communal Wastewater Treatment Plant (WWTP). The system represents an integrated domestic wastewater management model in the Special Region of Yogyakarta; however, it still faces several challenges related to service capacity, operational efficiency, and community participation in financing and infrastructure maintenance.

In addition, the Sewon District has diverse socioeconomic characteristics, including variations in income, education, and population density, making it an ideal location for analyzing community participation behavior in domestic wastewater management. These conditions are also relevant for exploring residents' willingness to pay (WTP) for sustainable wastewater services. Therefore, the selection of the Sewon Subdistrict provides a representative case for examining community-based wastewater management systems in rapidly urbanizing peri-urban areas. Therefore, this study aims to provide an empirical and analytical explanation of the relationship between socioeconomic factors, environmental perceptions, and community willingness to support the sustainability of communal wastewater treatment plants in densely populated urban areas such as the Sewon District.

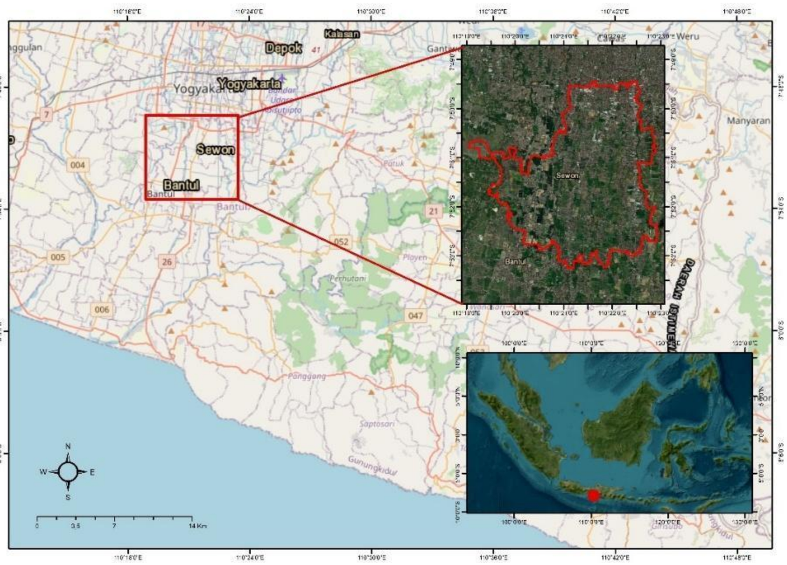

Figure 1. Location of the study area

2.2 Data Collection

This study employed a mixed methods approach, integrating quantitative and qualitative methods and combining primary and secondary data to gain a comprehensive understanding of domestic wastewater management in the Sewon District, Yogyakarta Special Region. A sequential explanatory design was applied, in which quantitative analysis was conducted as the primary stage, followed by qualitative exploration to strengthen the interpretation of the statistical findings. The quantitative component served as the main analytical approach, as it enabled the identification of relationships between variables through statistical analysis and provided objective, measurable, and generalizable results (Sugiyono, 2017). The qualitative component was applied as a complementary approach to provide contextual insights into the technical, social, and institutional aspects of the Household Connection (HC) system through in-depth interviews and document reviews. The mixed-methods design also enhances methodological triangulation, improving the robustness and interpretability of quantitative SEM findings.

The research sample size was determined using the Slovin formula to ensure the representativeness of the population while maintaining statistical accuracy. A 10% margin of error was selected considering the exploratory nature of the behavioral analysis and relatively similar residential and service characteristics within the study area. This precision level is commonly adopted in exploratory social and behavioral research, where behavioral constructs are examined at the community level. The Slovin formula is expressed as Equation (1):

$$n = \frac{N}{1 + N(e)^2} \#(1)$$

where n represents the sample size, N the total population, and e the margin of error (commonly set at 10% or 0.1). Based on the population of 35,890 households in the Sewon District, the sample size was calculated using Equation (2) as follows:

$$n = \frac{35{,}890}{1 + 35{,}890(0.1)^2} = 99.7 \approx 100 \#(2)$$

This sample size is considered adequate for Structural Equation Modeling (SEM) analysis, in line with the recommendations of Ketchen et al. (2013), who suggest a minimum sample size of five to ten times the number of indicators included in the SEM model. In this study, the total number of indicators used in the SEM model fell within the recommended ratio, ensuring statistical adequacy and model stability. Moreover, the relatively simple structural configuration with a limited number of latent constructs further supports estimation stability under this sample size limitation. Hair et al. (2019)also suggest that a minimum sample size of 100 is acceptable for covariance-based SEM when the model is relatively simple and theory-driven, as in this study's case.

Primary data were collected using a structured questionnaire administered to 100 respondents, including active and prospective users of the Household Connection (HC) system. A five-point Likert scale (1 = strongly disagree to 5 = strongly agree) was used to assess willingness to pay (WTP), perceptions of wastewater management effectiveness, and relevant socioeconomic factors according to Sekaran and Bougie (2016). Willingness to pay (WTP) was elicited using a contingent valuation approach with a payment card format, where respondents selected their maximum acceptable monthly tariff from a predefined range based on existing local sanitation fees. In this study, the structural model used a straightforward setup with a small number of latent variables and indicators, which helped minimize issues with unstable estimation (Kline, 2023). The questionnaire items were adapted from previous studies to ensure content validity and construct reliability. Prior to full data collection, the questionnaire was reviewed to ensure clarity of wording and contextual suitability for the local conditions of the Sewon District. To minimize hypothetical bias, respondents were informed that the survey aimed to support real policy planning for communal wastewater services and that their responses could influence future decisions regarding tariffs. A brief cheap talk script was included to encourage respondents to consider their actual household budget constraints when stating their willingness to pay.

Qualitative data were obtained through in-depth interviews with the Sewon Communal Wastewater Treatment Plant (WWTP) manager, local government representatives, and village officials to support the interpretation of quantitative findings by providing contextual insights into operational, technical, and institutional conditions. Secondary data were collected through document reviews of regional regulations, technical guidelines, and official reports on domestic wastewater management issued by the Public Works, Housing, and Settlement Area Service (DPUPKP) of the Special Region of Yogyakarta. The qualitative findings were primarily used to validate and interpret the statistically significant relationships identified in the SEM analysis.

2.3 Study Design

This study adopted a Structural Equation Modeling (SEM)-based analytical design within a dominant quantitative mixed-methods framework to analyze the factors influencing community willingness to pay (WTP) for domestic wastewater management services through the Household Connection (HC) system. The conceptual framework was adapted from Suhardono et al. (2025) and refined to fit the institutional and residential contexts of the Sewon District. The model was constructed deductively based on the established theoretical relationships between behavioral intention and institutional determinants.

The analytical framework integrates WTP estimation, SEM, and SWOT analysis to ensure consistency between the behavioral analysis and strategic formulation. WTP serves as the primary outcome variable, reflecting the community's financial support for sustainable communal wastewater treatment services. SEM was used to statistically examine the determinant factors, including environmental perceptions, inhibiting factors, and supporting institutional factors. Only statistically significant determinants validated through qualitative findings were incorporated into the IFAS and EFAS matrices for SWOT-based strategic development.

Structural Equation Modelling (SEM) was selected because it enables the examination of relationships among multiple latent variables and their observed indicators within a single integrated framework. This approach is particularly appropriate for analyzing behavioral constructs such as willingness to pay, which are influenced by both perceptual and institutional dimensions of sustainability. Covariance-based SEM (CB-SEM) was implemented using AMOS software to test theory-driven causal relationships and evaluate the overall model fit. Descriptive statistical analysis and preliminary data screening were conducted using SPSS prior to the SEM estimation (Abu-Bader and Jones, 2025). Model evaluation followed the standard goodness-of-fit criteria to ensure construct validity, reliability, and overall model adequacy before hypothesis testing.

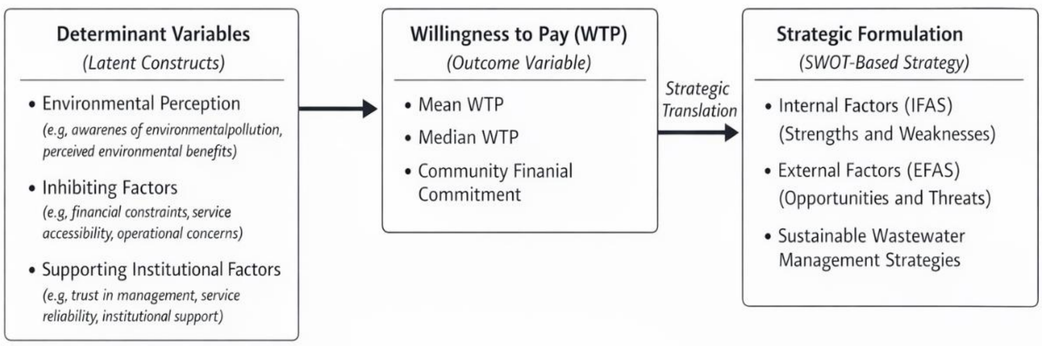

Figure 2. Conceptual framework

Figure 2 illustrates the sequential analytical workflow, including data collection, SEM estimation, validation of significant determinants, and translation into SWOT-based strategic formulation. The structural model includes four latent constructs: Environmental Perception (X2), Inhibiting Factors (X3), Supporting Factors (X4), and Willingness to Pay (Y). Community Participation (X1) was operationalized as a descriptive socioeconomic profile variable (education, employment status, and household expenditure) and was not modeled as a latent construct to avoid construct ambiguity and maintain model parsimony in the SEM estimation. All indicators were measured on a five-point Likert scale. The operationalization of the variables is presented in Table 1.

Table 1. Research variables and measurement indicators

Variable	Question Item	Relation to Wastewater Utilization Strategy and Sustainability of Communal WWTP Services
Community Participation (X1)	What is your highest level of education?	Education level influences environmental awareness and community participation in Communal WWTP management.
	Are you currently employed?	Employment status reflects financial capacity and economic stability, which affect the WTP.
	What is your average monthly expenditure?	Indicates the economic ability to pay for sustainable WWTP service.
Environmental Factors and Perceptions (X2)	How well do you understand the impact of domestic wastewater on the environment?	Environmental knowledge plays a key role in shaping awareness and sustainability.
	How concerned are you about maintaining cleanliness in your surroundings?	This reflects the ecological awareness that drives pro-environmental behavior.
	Have you ever participated in environmental activities (e.g., community clean-ups, reforestation, or waste banks)?	Active participation reflects social support for integrated waste management and circular economy.
	How do you rate the quality of the existing HC/WWTP services?	Positive perceptions increase trust and willingness to pay for sustainable services.
	How satisfied are you with the benefits of the Communal WWTP services?	Service satisfaction encourages participation and sustainability of community contribution.
Inhibiting Factors (X3)	Do you feel that the wastewater management fee is burdensome?	Identifies economic barriers to community participation in the WWTP Program.
	Is your house far from the HC/WWTP network?	Location affects accessibility and participation in wastewater management.
	Are WWTP services easily accessible and affordable for the community	Service affordability is a key factor in the implementation of sustainable wastewater management.
Supporting Factors (X4)	Are you aware of wastewater utilization for liquid fertilizer or *biogas* production?	Knowledge of wastewater utilization supports circular economy strategies and resource efficiency.
	In your opinion, how important is the community's role in Communal WWTP management?	Strengthening community collaboration in sustainable waste management strategies.
	Are you aware of government or institutional support for domestic	Regulatory and institutional support reinforces the sustainability of

Variable	Question Item	Relation to Wastewater Utilization Strategy and Sustainability of Communal WWTP Services
	wastewater management?	Communal WWTP services.
Willingness to Pay (Y)	How much are you willing to pay monthly for WWTP services?	It measures community capacity and willingness to pay for sustainable WWTP services.
	Would you be willing to pay a higher fee for improved WWTP services?	Assesses the potential for increased financial contributions based on service quality and benefits.
	Are you willing to participate in a long-term payment (sustainability) scheme?	It measures long-term community commitment to supporting wastewater management sustainability.
	In your opinion, is the service fee proportional to the quality of the wastewater management?	Reflects the balance between the cost and sustainability benefits received.

2.4 SEM Analysis

Structural Equation Modelling (SEM) analysis was conducted using AMOS software to examine the causal relationships among latent variables and their indicators. The latent variables included supporting and inhibiting factors, community perception, and willingness to pay. Community participation was assessed as a descriptive and contextual variable to support the interpretation of wastewater management conditions; therefore, it was not included in the structural model. As illustrated in Figure 3, the SEM input model was designed to depict the hypothesized relationships among the latent variables and their respective indicators.

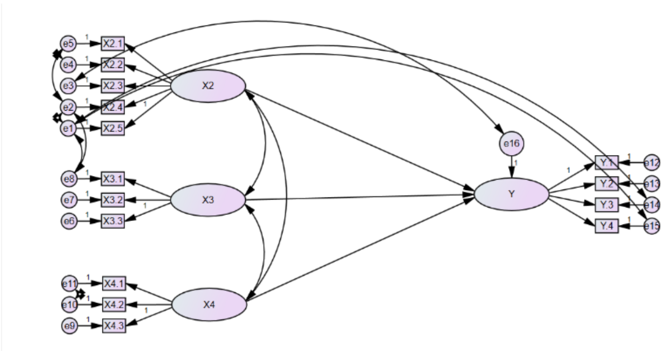

Figure 3. Input structural equation modelling analysis

SEM analysis was conducted in two main stages. The first stage was the measurement model, which aimed to test the validity and reliability of each construct. Indicator validity was assessed using a minimum factor loading value of 0.50, while construct reliability was evaluated using Composite Reliability (CR) and Average Variance Extracted (AVE) values (Lim, 2024). Model modification indices were considered only when theoretically justified to improve the goodness-of-fit without compromising conceptual consistency.

The second stage was the structural model, which tested the relationships among the latent variables based on the path coefficients. Model fit was evaluated using several goodness-of-fit (GOF) indices, including CMIN/DF, RMSEA, CFI, and TLI. The model was considered acceptable if it met the following criteria: CMIN/DF < 3, RMSEA < 0.08, and CFI and TLI > 0.90. These stages ensured that the developed model demonstrated a good fit between empirical data and the proposed theoretical structure.

2.5 Data Analysis

The results of the Structural Equation Modeling (SEM) analysis were interpreted to identify the direct and indirect effects of the variables influencing community willingness to pay (WTP) and the sustainability of the communal wastewater treatment system. Quantitative findings were complemented by qualitative data from in-depth interviews and policy document reviews to provide a contextual understanding of the social, economic, and institutional conditions in the study area.

Based on the integration of quantitative and qualitative findings, a circular economy-based domestic wastewater management strategy was formulated, emphasizing management efficiency, optimization of wastewater utilization, and strengthening community participation in system financing and maintenance. To support strategic formulation, this study also applied SWOT analysis using the Internal Factor Analysis Summary (IFAS) and External Factor Analysis Summary (EFAS) matrices. The SWOT analysis served as a strategic synthesis of the SEM results and qualitative insights, providing a structured basis for developing sustainable domestic wastewater management policies and strengthening the long-term sustainability of the Communal Wastewater Treatment Plant (WWTP) system. Strategic recommendations were formulated only after confirming statistically significant determinants from the SEM results and validating them with qualitative findings.

The sequential integration of SEM and SWOT ensures that strategic recommendations are directly derived from empirically validated determinants of willingness to pay, strengthening the policy relevance of the findings. SEM focuses on explaining which factors have a significant impact on the willingness to pay, whereas SWOT examines the strategic and policy formulation dimensions of how sustainability strategies should be developed, based on factors that have been proven through empirical research. This step-by-step integration ensures that strategic and policy recommendations are directly derived from empirically validated determinants of the willingness to pay, thereby strengthening the practical applicability of domestic wastewater management policies in urban residential areas.

3 Result and Discussion

3.1 Community Socioeconomic

The respondents in the study 'Sustainable Management and Community Willingness to Pay for Communal Wastewater Treatment Services in the Special Region of Yogyakarta' consisted of community members who are current or prospective users of the House Connection (HC) system and who play a role in environmental management around the Communal Wastewater Treatment Plant (WWTP). The total number of respondents was 100. The collected characteristics included gender, age, highest level of education, occupation, number of family members, and monthly income level. Table 2 presents the respondent demographics.

Table 2. Respondent demographics

Variables		Value	Percent (%)
Gender	Male	57	57.00
	Female	43	43.00
Age	20 -39	56	56.00
	40 – 59	36	36.00
	60 – 80	8	8.00
Education Levels	Elementary School	1	1.00
	Junior High School	4	4.00
	Senior High School	41	41.00
	Bachelor's, Master's, Doctorate, or equivalent	54	54.00
Outcome	< IDR 2,360,533	32	32.00

Variables	Value	Percent (%)
> IDR 2,360,533	68	68.00

The results show that the majority of respondents were male (57 respondents or 57.00%), while females accounted for 43 respondents (43.00%). This proportion indicates that men were slightly more dominant in completing the questionnaire, possibly because data collection took place during non-working hours, when more men were at home. Nevertheless, both men and women play essential roles in household waste management, particularly in supporting the Communal WWTP system through proper waste disposal practices. The age distribution reveals that the 20–39 year group was dominant (56 respondents or 56.00%), followed by the 40–59-year group (36 respondents or 36.00%), and the 60–80 year group (8 respondents or 8.00%). The average respondent age was approximately 40 years, indicating that most participants were in their productive work years. According to Meidiana et al. (2021), age is an important factor in determining an individual's decisions, particularly regarding waste management behavior.

The respondents' education levels were also relatively high. Those with higher education (Bachelor's, Master's, Doctorate, or equivalent) constituted the largest group (54 respondents or 54.00%), followed by Senior High School (41 respondents or 41.00%), Junior High School (4 respondents or 4.00%), and Elementary School (1 respondent or 1.00%) education. This shows that most respondents had secondary to tertiary education. Education can serve as a means for individuals to gain knowledge about environmental protection, acquire information on the importance of waste management, and provide guidance on behaviors that positively impact waste management (Isni and Mustanginah, 2023).

In terms of household expenditure, the classification was based on the 2025 Bantul Regency Minimum Wage (IDR 2,360,533). The findings indicate that most respondents (68 people or 68.00%) had monthly expenditures exceeding the regional minimum wage, whereas 32 respondents (32%) spent less. This suggests that most respondents belonged to middle-to upper-income households, which may indicate a higher willingness to pay for domestic wastewater management services. This condition demonstrates the community's financial capacity to participate in the operational funding of the Communal Wastewater Treatment Plant (WWTP), either in the form of monthly fees or contributions to the maintenance of the House Connection (SR) system. These socioeconomic characteristics indicate that the sample represents households with relatively adequate economic capacity and educational backgrounds, which is relevant for interpreting willingness-to-pay responses and behavioral determinants in the SEM analysis.

3.2 House connection (HC) system Mechanism

Observations and interviews with the management of the Bantul Urban Area Domestic WWTP revealed that the House Connection (HC) mechanism to the Communal WWTP in Sewon has become an integral component of domestic wastewater management in the region. The HC program represents one of the Bantul Regency Government's strategic initiatives to develop a centralized, network-based domestic wastewater system aimed at reducing environmental pollution caused by untreated household discharges into surface water. Through this system, wastewater from household activities, such as bathing, washing, cooking, and toilet use, is conveyed through a network of pipelines to the treatment plant, where it is fully processed before being discharged back into the environment.

The program was first launched in 2009 with technical support from both the national and local governments of Brazil. However, during its early implementation, the initiative faced several technical and social challenges, including limited pipeline infrastructure, low public understanding of wastewater management benefits, and insufficient institutional capacity. After evaluation and system improvements, in 2013, the program resumed with a pilot test involving 200 HC units in Kasihan Subdistrict, Bantul Regency, serving as a model project for the Sewon WWTP connection system.

The management and operation of the HC system are regulated under the Ministry of Public Works and Public Housing Regulation (Permen PUPR) No. 4/PRT/M/2017 on Domestic Wastewater

Management Systems. This regulation provides a legal framework for defining technical standards, institutional roles, and the responsibilities of local governments and communities in managing household connections and centralized wastewater systems. At the regional level, this regulation is reinforced by Bantul Regency Local Regulation (Perda Bantul) No. 10 of 2013 on Domestic Wastewater Management, which serves as the legal basis for implementing the HC and WWTP Sewon services. It outlines service management, financing mechanisms, and the responsibilities of users and operators, thereby supporting a sustainable sanitation system focused on improving environmental quality and public health.

Wastewater flow begins at household sources, including bathrooms, kitchens, laundry areas (grey water), and toilets (black water). Wastewater flows through internal household pipes into an inspection chamber or a HC connection box. From there, it enters lateral pipelines connecting several houses within the neighborhood. These laterals connect to sub-main or trunk sewers, which channel wastewater to the main area-level pipeline. In low-lying areas, pumping stations assist the flow; otherwise, the system generally operates by gravity, utilizing natural land gradients to direct wastewater to the Sewon WWTP without additional energy input.

Each HC unit includes an inspection chamber for maintenance access and to prevent the occurrence of blockages. Wastewater from the main pipe enters the Sewon WWTP through an inlet and distribution manhole, then flows into a sump pit for initial collection before passing through a mechanical screening to remove large solids, such as plastics, fabrics, and wood debris. Next, the wastewater enters the grit chamber to settle inorganic materials such as sand and gravel, followed by the equalization tank, which stabilizes flow rates and pollutant concentrations to optimize biological processes.

The biological treatment stage occurs in a Sequencing Batch Reactor (SBR), which combines anaerobic and aerobic phases to decompose organic matter and reduce BOD, COD, nitrogen, and phosphorus levels. The treated water then flows to the maturation pond for further polishing and sedimentation. Before discharge, the wastewater passes through a chlorination tank, where chlorine compounds are added to disinfect pathogenic microorganisms. Finally, the treated effluent meeting environmental quality standards is released into the Bedog River, which is the designated receiving body.

Beyond the technical process, community participation plays a vital role in maintaining the sustainability of the HC system. Residents contribute not only as users but also through monthly fee payments and collective maintenance. According to interviews with the Sewon WWTP management unit, one of the persistent challenges is the low awareness among some residents in performing regular self-maintenance, particularly in densely populated areas. To address this, the local government and Bantul Domestic Wastewater Management Unit conduct routine monitoring of effluent quality and ensure that all pipelines and treatment units operate optimally, without leaks or blockages. These efforts are essential for maintaining the operational sustainability of the Sewon WWTP and advancing sustainable wastewater management in Bantul's urban areas. This technical and institutional context provides the operational basis for analyzing community willingness to pay and governance-related factors examined in the SEM model.

3.3 Willingness to Pay

Based on the questionnaire responses from 100 participants in the Sewon Subdistrict, data were obtained regarding the community's willingness to pay for Communal WWTP services. The willingness to pay values were elicited using a payment card approach, where respondents selected a predefined contribution range that best represented their maximum monthly willingness to pay for communal wastewater services. To minimize hypothetical bias, respondents were presented with a realistic scenario describing the current operational costs, service benefits, and financial constraints of the communal wastewater system before stating their willingness to pay. The results are shown in Table 3.

Table 3. Distribution of community willingness to pay in sewon subdistrict

No	Contribution Range (IDR/month)	Number of Respondents (people)	Percentage (%)
1.	< 5,000	3	3
2.	5,000 – 7,000	24	24
3.	7,000 – 10,000	47	47
4.	10,000 – 15,000	20	20
5.	> 15,000	5	5
Total		100	100

Based on Table 3, most respondents were willing to pay between Rp7,000 and Rp10,000 per month (47 people, 47.00%). This indicates that nearly half of the community considers this amount reasonable and affordable for financing domestic waste management. The average (mean) willingness to pay among the community was IDR 7,113.86 per month, while the median value reached IDR 7,500. The small difference between the mean and median indicates a relatively consistent willingness of approximately IDR 7,500 per month. A total of 24 respondents (24.00%) were willing to pay between Rp5,000 and Rp7,000 per month, whereas 20 respondents (20.00%) were willing to pay between Rp10,000 and Rp15,000 per month. Meanwhile, only five respondents (5.00%) were willing to pay more than Rp15,000 per month, and three respondents (3.0%) were willing to pay less than Rp5,000 per month. This distribution indicates that the majority of the community falls within the medium willingness-to-pay range, reflecting a balance between economic capacity and the perceived benefits of communal wastewater treatment services. This aligns with Rahayu et al. 's (2022) findings, which explain that the community's willingness to pay for sanitation services is generally proportional to their level of knowledge and perceived benefits, rather than being solely influenced by income levels.

To provide a more detailed picture of the distribution of willingness to pay values, the results of the descriptive statistical analysis are presented in Table 4.

Table 4. Descriptive analysis of community willingness to pay in sewon subdistrict

Statistic	Value
Respondents (N)	100
Minimum	3,000
Maximum	13,500
Mean	7,113.86
Median	7,500
Standard Deviation	2,068.67
Skewness	0.775
Kurtosis	0.890

Based on Table 4, the median willingness to pay among residents in the Sewon District is recorded at IDR 7,500 per month, indicating that most respondents are inclined to pay around this amount. The median value is considered more robust for policy reference because it is less sensitive to extreme values than the mean, providing a realistic benchmark for tariff-setting decisions. The range of willingness to pay spans from IDR 3,000 to IDR 13,500 per month, reflecting the heterogeneity of respondents' economic capacity; however, the majority falls within the IDR 7,000–10,000 range. This condition indicates the community's potential to contribute financially to the sustainability of the communal wastewater treatment system, making the median value of IDR 7,500 a useful reference for local government and WWTP Sewon managers in setting contribution rates that align with residents' economic capacity while supporting the operational sustainability of domestic wastewater management (Setiawan and Suryandari, 2023). This WTP level suggests that community-based tariff schemes should be designed within this affordability range to ensure cost recovery while maintaining the inclusiveness of lower-income households.

3.4 Structural Equation Modeling (SEM) Results

The relationship between variables in this study was analyzed using the Structural Equation Modeling (SEM) approach. Although the sample size of 100 respondents is relatively small for covariance-based SEM, it is considered acceptable for a model with a limited number of latent variables and indicators, which helps minimize estimation instability and the model complexity (Hair et al., 2021). Recent SEM methodological guidelines also suggest that models with limited constructs and high communalities can yield stable estimates, even with sample sizes of approximately 100 (Kline, 2023). This method was chosen because it can explain the simultaneous causal relationship between latent variables and their indicators, as well as test the relationship between exogenous and endogenous variables in a single integrated structural model. The analysis was conducted based on primary data obtained from questionnaires distributed to 100 respondents who were users of the Sewon Communal Wastewater Treatment Plant (WWTP) service in Sewon District, Bantul Regency. Table 5 presents the results of the construct validity and reliability tests measured using Average Variance Extracted (AVE), Cronbach's Alpha, and Composite Reliability (CR).

Table 5. Construct validity and reliability results

No	Variable	AVE	*Cronbach's Alpha*	*Composite Reliability*
1.	Willingness to Pay	0.631	0.926	0.929
2.	Environmental Perception	0.608	0.903	0.895
3.	Inhibiting Factors	0.803	0.816	0.822
4.	Supporting Factors	0.766	0.903	0.924

Convergent validity was measured using Average Variance Extracted (AVE) to assess the extent to which indicators explained the variance of each construct. According to Hair et al. (2021), a construct is considered to have good convergent validity if AVE > 0.50. As shown in Table 5, all variables have AVE values above 0.50, ranging from 0.608 for Environmental Perception to 0.803 for Inhibiting Factors, indicating that each construct consistently and significantly explains its variables. These results also confirm that the respondents understood the questionnaire statements well and provided consistent answers regarding social, economic, and environmental aspects (Halimoon et al., 2021).

Construct reliability was further evaluated using Cronbach's Alpha and Composite Reliability (CR). All variables demonstrated high internal consistency, with Cronbach's alpha values ranging from 0.816 to 0.926 and CR values from 0.822 to 0.929, exceeding the recommended thresholds (Halimoon et al., 2021). Willingness to Pay had the highest reliability (α = 0.926; CR = 0.929), reflecting stable perceptions of the respondents regarding their financial contributions to communal wastewater management, while Inhibiting Factors had the lowest reliability (α = 0.816; CR = 0.822) but still met the minimum criteria. Overall, these findings confirm that all constructs are valid and reliable, providing a solid foundation for further SEM analysis of the relationships between environmental perception, supporting and inhibiting factors, and community willingness to pay (Pratiwi and Kurniawan, 2023). These SEM findings provide an empirical basis for subsequent SWOT-based strategic formulation, where statistically significant determinants are translated into internal and external strategic factors.

The goodness-of-fit (GOF) test was conducted to assess the extent to which the developed structural model was consistent with the empirical data from the study. This analysis uses primary data from questionnaires distributed to 100 respondents who are users of communal wastewater treatment services in the Sewon District, Bantul Regency. The purpose of this test was to ensure that the model describing the relationship between socioeconomic factors, environmental perceptions, supporting factors, and community willingness to pay for domestic wastewater management services through house connections (HC) was consistent with field conditions. According to Ferdinand (2011) and Hair et al.

(2021), the Goodness of Fit test can be performed using several main indices, namely CMIN/DF, Standardized Root Mean Square Residual (SRMR), Root Mean Square Error of Approximation (RMSEA), Comparative Fit Index (CFI), and Tucker Lewis Index (TLI). The model is said to be fit if all indicators meet the recommended value.

Table 6. Goodness of fit model structural equation modeling

Indicator	Standard	Value	Remarks
CMIN/DF	≤ 5.0	1.273	Fit
SRMR	≤ 0.08	0.029	Fit
RMSEA	≤ 0.08	0.052	Fit
CFI	≥ 0.9	0.985	Fit
TLI	≥ 0.9	0.978	Fit

Based on the Goodness of Fit test results in Table 6, all indicators show that the model meets the required criteria and can be considered acceptable. The CMIN/DF value of 1.273 indicates that the relationships between the variables in the model reflect real conditions in the field, meaning that the model is neither overly complex nor too simplistic in explaining the phenomena studied. The SRMR value of 0.029 suggests a minimal difference between the model's predicted results and the actual respondent data, implying that the model adequately represents how the community perceives and responds to domestic wastewater management through Communal Wastewater Treatment Plant (WWTP). In other words, the relationships constructed in the model reflect the actual behavior and perception of the community.

Furthermore, the RMSEA value of 0.052 indicates a relatively low level of model error, meaning that the model can effectively represent the relationships between variables in the studied population, particularly in explaining factors influencing community willingness to pay for wastewater management services. The CFI value of 0.985 and TLI of 0.978, both above the minimum thresholds, indicate an excellent model fit. These results reinforce that the variables included in the model are relevant and interconnected in explaining the community's financial contribution to the sustainability of the Communal Wastewater Treatment Plant (WWTP). Overall, the model structure explaining the relationships between environmental perception, inhibiting factors, and supporting factors in influencing willingness to pay is statistically valid and empirically relevant. However, only the Supporting Factors demonstrated a statistically significant direct effect on Willingness to Pay, whereas Environmental Perception and Inhibiting Factors did not show statistically significant effects. This confirms that institutional support, regulatory clarity, and governance mechanisms, rather than environmental awareness alone, are the primary determinants of willingness to pay for domestic wastewater management (Pratiwi and Kurniawan, 2023).

Based on Figure 4, the results output of the analysis using the Structural Equation Modeling (SEM) method show that the research model has met the Goodness of Fit criteria with a chi-square value of 9.439, probability of 0.056, GFI of 0.885, AGFI of 0.831, RMSEA of 0.052, TLI of 0.978, NFI of 0.933, PCFI of 0.703, and PNFI of 0.667. All indicator values were within the recommended acceptance range; therefore, the model was declared suitable for use in analyzing the relationship between variables. These criteria are in line with the guidelines of Hair et al. (202),whoh state that a structural model can be categorized as fit if it has a GFI value > 0.80, TLI and NFI > 0.90, and RMSEA < 0.08.

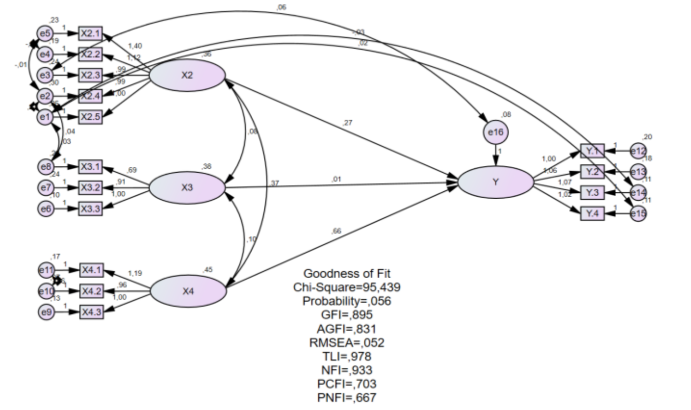

Figure 4. Output result structural equation modeling analysis

The results of the significance test between variables presented in Table 7 show the direction and strength of the SEM significance test results of the influence of the independent variables (X2: Environmental Perception, X3: Inhibiting Factors, X4: Supporting Factors) on the dependent variable Y (Willingness to Pay).

Table 7. Structural equation modeling significance test results

Dependent Variable	Variable	Estimate	*T- statistic*	*P-Value*
Y	X2	0.274	1.144	0.253
	X3	0.014	0.241	0.810
	X4	0.664	3.084	0.002

The Estimate value indicates the magnitude of the effect, while the p-value is used to determine the significance of the relationships between variables, with a significance criterion of p-value < 0.05. As shown in Table 7, variable X2 (Environmental Perception) has an estimate of 0.274 and a p-value of 0.253, indicating no significant effect on Willingness to Pay (Y). These results indicate that environmental perception should be interpreted as a contextual variable rather than a direct behavioral driver of financial contribution decisions. This suggests that although the community holds certain views or evaluations regarding environmental conditions and management, these perceptions are not yet strong enough to motivate financial contributions to the cause. Therefore, environmental perception cannot be interpreted as a direct determinant of willingness to pay in this study, but rather as a contextual factor that may support pro-environmental attitudes without necessarily translating into economic commitment. This finding aligns with Harun et al. (2022), who stated that environmental perception only affects willingness to pay when the community experiences direct and tangible benefits from waste management services.

Meanwhile, variable X3 (Inhibiting Factors) in Table 7 has an estimate of 0.014 and a p-value of 0.810, which also indicates an insignificant effect on Willingness to Pay. This suggests that perceived barriers function more as background conditions and do not directly suppress the willingness to pay in the observed sample. For example, limited information, insufficient socialization, and the perception that waste management is solely the government's responsibility are not primary determinants in the community's decision to pay for Communal Wastewater Treatment Plant (WWTP) services. The statistical insignificance indicates that perceived barriers do not directly suppress payment decisions in the observed sample. The low influence of this variable may be due to the community's limited understanding of the benefits of Communal Wastewater Treatment Plant (WWTP) for environmental quality and public health. This result is consistent with Rachmawati and Suryani (2020), who found that perceptual and structural barriers do not necessarily correspond directly to financial contribution willingness, particularly in areas with low sanitation awareness. Therefore, policy interventions focusing solely on awareness campaigns may have a limited impact unless accompanied by institutional and governance-strengthening measures.

In contrast, variable X4 (Supporting Factors), as presented in Table 7, has an estimate of 0.664 with a p-value of 0.002, indicating a positive and significant effect on Willingness to Pay (Y). This suggests that stronger institutional support, government regulations, and community participation lead to a higher willingness to financially contribute to the sustainability of Communal Wastewater Treatment Plants (WWTP). This finding is consistent with previous studies highlighting the importance of institutional trust, governance structures, and regulatory frameworks in influencing community payment behavior for sanitation services, and is reinforced by Willetts et al. (2020), who reported that strengthening institutional frameworks and incentive policies significantly increases community commitment to paying for waste management services. However, this contrasts with findings in high-income contexts, where environmental awareness plays a stronger role in determining willingness to pay (Pham *et al.*, 2023).

3.5 Strategic Formulation

This sequential integration ensures that SWOT factors are empirically derived from behavioral determinants rather than purely qualitative judgments. The strategic formulation presented in this study was directly derived from the empirical data obtained from the SEM analysis. Conceptually, the analytical framework in this study follows a sequential flow: (1) estimation of the willingness to pay, (2) identification of behavioral determinants using SEM, and (3) strategic formulation using SWOT analysis. The SEM results, particularly the significant role of Supporting Factors, were translated into internal and external strategic factors in the IFAS and EFAS matrices to ensure that strategic recommendations are empirically grounded rather than descriptive. Variables that demonstrate a considerable effect on the community's willingness to pay are interpreted as critical leverage points for sustainable WM. These findings were then synthesized with qualitative insights from institutional interviews to construct the IFAS and EFAS matrices, ensuring consistency between the quantitative results and strategic recommendations.

The Internal Factor Analysis Summary (IFAS) matrix was employed to evaluate the key internal strengths and weaknesses influencing domestic wastewater utilization at the Sewon Communal Wastewater Treatment Plant (WWTP). This analysis assigns weights and ratings to each internal factor, where the total weight does not exceed 1.00 and the ratings range from 1 (poor) to 4 (very strong). The detailed results of the IFAS matrix are listed in Table 8.

Table 8. Internal factor analysis summary (IFAS)

No	Internal Factors	Weight	Rating	Score
Strengths				
S1	SBR-based WWTP technology produces stable treated effluent suitable for reuse	0.10	4	0.40
S2	Treated sludge has potential for compost and liquid organic fertilizer (LOF)	0.09	4	0.36
S3	Affordable user fee (IDR 3,000–5,000 per household)	0.08	3	0.24
S4	Regulatory and institutional support enables wastewater utilization innovation	0.10	4	0.40
S5	Relatively high community environmental awareness	0.07	3	0.21
Total Strengths (S)		0.44		1.61
Weakness				
W1	Limited utilization of treated effluent and sludge	0.10	2	0.20
W2	Absence of dedicated unit for value-added waste processing	0.10	2	0.20
W3	Limited innovation in reuse of treated water and sludge	0.09	2	0.18

No	Internal Factors	Weight	Rating	Score
W4	Low public understanding of wastewater utilization potential	0.09	2	0.18
W5	Low willingness to pay for wastewater utilization innovation	0.08	2	0.16
Total Weaknesses (W)		0.46		0.92
Total IFAS Score		**1.00**		**2.53**

As shown in Table 8, the total IFAS score of 2.53 indicates that the internal condition of the Sewon Communal WWTP is moderately strong in supporting the development of domestic wastewater. The main internal strengths are associated with the application of Sequencing Batch Reactor (SBR) technology, which is capable of producing a relatively stable treated effluent suitable for potential reuse. In addition, the treated sludge generated from the process has considerable potential for reuse as compost or liquid organic fertilizer. These findings are consistent with those of Zorpas (2020), who emphasized that the stability of biological treatment processes is a key prerequisite for advancing waste utilization within a circular economy framework. Beyond technological factors, regulatory and institutional support represents an important strength in creating a conducive environment for innovation in wastewater utilization. Such support enables the integration of technical solutions and governance mechanisms. Although environmental awareness is included as an internal strength, the SEM results indicate that it does not directly influence the willingness to pay; therefore, it is considered a supporting contextual factor rather than a primary financial driver.

Nevertheless, the IFAS analysis also identified several internal weaknesses that need to be addressed to maximize utilization potential. One of the main weaknesses is the low level of actual reuse of treated effluent and sludge, despite their technical feasibility of reuse. In addition, the absence of a dedicated unit for processing wastewater by-products into value-added products limits the practical implementation of reuse strategies in the industry. Limited public understanding of wastewater reuse potential further constrains community participation and its acceptance. These conditions suggest a gap between the existing technical capacity and its effective application in practice. This finding supports Willetts et al. (2020), who noted that the success of communal sanitation systems depends not only on infrastructure but also on institutional capacity and social acceptance of the system. Therefore, strengthening operational management, promoting advanced technological innovation, and enhancing community education are essential to ensure optimal wastewater utilization at the Sewon WWTP and provide sustainable long-term benefits.

The External Factor Analysis Summary (EFAS) matrix was used to assess opportunities and threats arising from the external environment that may influence the development of domestic wastewater utilization in the region. Similar to the IFAS approach, weights and ratings were assigned to each external factor, and the results are presented in Table 9.

Table 9. External factor analysis summary (EFAS)

No	Faktor Eksternal	Bobot	Rating	Skor
Opportunities				
O1	Large market potential for compost and LOF from WWTP sludge	0.12	4	0.48
O2	High demand for organic fertilizer from farmer groups and MSMEs	0.10	4	0.40
O3	Government support for circular economy and waste utilization	0.08	3	0.24
O4	Active involvement of environmental communities	0.08	3	0.24
Total Opportunities (O)		0.38		1.36
Threats				
T1	Unstable and limited compost/LOF market	0.12	2	0.24
T2	Public hesitation toward waste-based products	0.10	2	0.20
T3	Limited funding for wastewater utilization facilities	0.10	2	0.20

No	Faktor Eksternal	Bobot	Rating	Skor
T4	Solid waste contamination affecting effluent and sludge quality	0.10	2	0.20
Total Threats (T)		0.42		0.84
Total EFAS		**1.00**		**2.20**

Based on Table 9, the total EFAS score of 2.20 indicates that the external environment is moderately supportive of domestic wastewater utilization at the Sewon Communal WWTP, Yogyakarta. Key opportunities arise from the increasing demand for organic fertilizers among farmers and micro, small, and medium enterprises (MSMEs), along with strong government support for circular economy initiatives and wastewater reuse programs. These external conditions create a favorable context for expanding the utilization of treated effluent and sludge as value-added products. These findings are consistent with Ghisellini et al. (2021), who emphasized that public policy frameworks and market demand play a central role in enabling successful circular economy implementation. In addition, the involvement of environmental communities provides further opportunities for collaboration, awareness, and capacity building. Collectively, these opportunities suggest that external drivers can significantly reinforce internal strengths if effectively leveraged.

However, several external threats must be carefully managed, as summarized in Table 9. These include market instability for compost and liquid organic fertilizer (LOF) products, public skepticism toward products derived from wastewater, and limited financial resources for developing and utilizing infrastructure. Another critical challenge is the risk of solid waste contamination, which may reduce the quality of the treated effluent and sludge and undermine market acceptance. These threats highlight the vulnerability of wastewater utilization initiatives to both economic and social factors. Without adequate safeguards, these challenges could hinder the long-term viability of reuse programs. Therefore, integrating risk mitigation measures, such as quality assurance, public communication, and diversified funding mechanisms, is essential to ensure the sustainability of wastewater utilization strategies at the Sewon Communal WWTP in Yogyakarta.

Furthermore, the IFAS–EFAS analysis was conducted to assess the relative influence of internal and external factors affecting domestic wastewater utilization at the Sewon Communal Wastewater Treatment Plant (WWTP). The evaluation results were then processed to calculate the score differentials between strengths and weaknesses and between opportunities and threats. These differential values were used to determine the strategic position within the SWOT Cartesian diagram. The resulting SWOT quadrant diagram is shown in Figure 5.

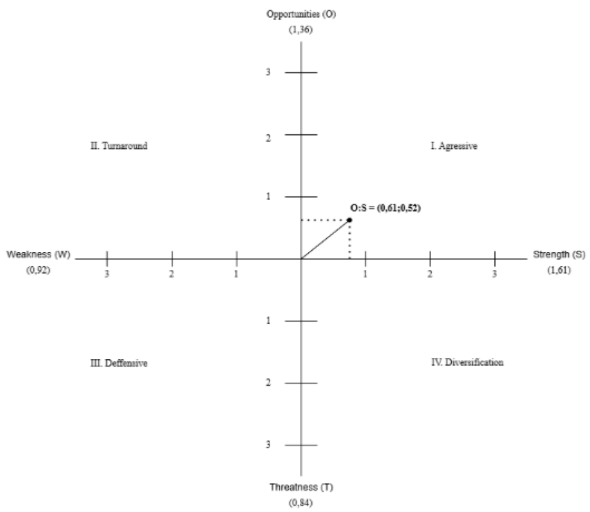

Figure 5. Strengths, weaknesses, opportunities, and threats cartesian diagram

Based on Figure 5, the analysis shows that the SWOT Cartesian diagram is divided into four quadrants: Quadrant I (Aggressive), Quadrant II (Turnaround), Quadrant III (Defensive), and Quadrant

IV (Diversification). In Quadrant I, the strength (S) and opportunity (O) scores were 1.61 and 1.36, respectively, whereas Quadrant II consisted of opportunity (O) at 1.36 and weakness (W) at 0.92. Quadrant III consists of weakness (W) at 0.92 and threat (T) at 0.84, and Quadrant IV consists of threat (T) at 0.84 and strength (S) at 1.61. The score differential calculation shows that the SWOT Cartesian diagram is located in Quadrant I (Aggressive), with a coordinate point of (0.61; 0.52), where the horizontal value of 0.61 is derived from the difference between strengths and weaknesses, and the vertical value of 0.52 is derived from the difference between opportunities and threats. The aggressive strategy position indicates that the Sewon WWTP has both technical and institutional readiness to expand wastewater utilization initiatives, provided that governance mechanisms and financial structures are strengthened. This position indicates that internal strengths and external opportunities dominate over weaknesses and threats, making an aggressive strategy the primary choice for the development of domestic wastewater utilization at the Sewon Communal Wastewater Treatment Plant (WWTP) (Yasra and Pratama, 2021).

Based on its position in Quadrant I, the recommended SO strategies include optimizing WWTP technology to produce treated water and sludge ready for utilization, developing compost or POC products from sludge as part of a circular economy, and engaging the community in education and proper waste utilization. These strategies allow the system to leverage its internal strengths while taking advantage of external opportunities to enhance wastewater treatment performance, generate value-added products, and strengthen community participation. This aggressive approach is proactive and growth-oriented, ensuring that technical, economic, and environmental potentials are maximized for sustainable development.

The formulation of these priority strategies reflects the principles of participatory management and sustainability in the field of environmental governance. The participatory principle is demonstrated through community involvement in fee payments, maintenance of household connection networks, and engagement in education and waste utilization activities. The sustainability principle is realized through the optimization of WWTP technology and the reuse of treated water and sludge as value-added products, ensuring that wastewater management not only controls pollution but also delivers long-term environmental and economic benefits (Willetts, 2020; Zorpas and Lasaridi, 2021). This aggressive strategy aligns with the system's main strengths, including stable technological capacity, the potential of sludge as a raw material for value-added products, and market opportunities for organic fertilizers among farmers' groups and small and SMEs. By implementing a strategy that is adaptive to social and economic conditions, wastewater utilization can enhance the perceived value of WWTP services and encourage increased community willingness to pay, thus ensuring the operational sustainability of the Sewon Communal WWTP. The dominance of supporting institutional factors implies that policy interventions should prioritize strengthening governance mechanisms, transparent tariff-setting systems, and stakeholder engagement rather than relying solely on environmental awareness campaigns. Future studies should explore longitudinal behavioral changes and test alternative tariff scenarios to validate the stability of willingness to pay over time.

4 Conclusions

This study aimed to measure community willingness to pay (WTP) for communal wastewater treatment services, identify its determinants using structural equation Modelling (SEM), and formulate sustainability strategies through SWOT analysis. The findings show that only Supporting Factors related to institutional strength and governance mechanisms have a statistically significant positive effect on WTP, while Environmental Perception and Inhibiting Factors do not demonstrate significant direct effects, indicating that institutional credibility, regulatory clarity, and service reliability constitute the primary drivers of financial participation rather than environmental awareness alone. The SWOT analysis positioned the strategy in Quadrant I (Aggressive) with coordinates (0.61; 0.52), suggesting that internal strengths and external opportunities outweigh weaknesses and threats; therefore, SO strategies such as optimizing WWTP technology, developing value-added products from sludge within a circular economy framework, and strengthening community engagement are recommended. From a policy perspective, efforts should prioritize institutional strengthening, improving service quality, transparent tariff management, and collaborative governance. Despite its contributions, this study is limited by its relatively small sample size and focus on a single region. Future research should expand the study area, apply comparative or longitudinal approaches, and explore alternative valuation methods to enhance robustness and generalizability.

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Ethics Statement

This study was conducted according to the guidelines of the Research and Community Service Institute (LPPM) Ethics Education and was approved by Universitas Sebelas Maret (UNS). Informed consent to participate was obtained from all participants.

CRediT Author Statement

Hashfi Hawali Abdul Matin: Conceptualization, Methodology, Data Curation, Investigation, Software, Visualization**. Julianatasya Tantri Damayanti:** Formal analysis, Investigation, Writing – original draft, Data interpretation. **Siti Rachmawati:** Main supervision, Methodology review, Review and Editing. **Sapta Suhardono:** Co-supervision, Methodology guidance, Review and Editing. **Lia Kusumaningrum:** Technical Support, Data validation, Review. **Budiyono:** Analytical Support, Interpretation of Results, Manuscript Revision. **Callista Fabiola Candraningtyas:** Language Editing, Structural Revision, Final Proofreading.

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