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Analysis of Management Policies and Technology Implementation for Sustainable Waste Management in Pekanbaru City

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Abstract
Sustainable waste management is a major challenge for rapidly growing cities like Pekanbaru. This study aims to analyze the effectiveness of waste management policies and the implementation of digital technology to support urban sustainability. As waste volume increases annually, management complexity necessitates a transition from traditional methods to integrated technological solutions. This research employed a mixed-methods approach. Qualitative data were gathered through in-depth interviews with 6 key informants, including government officials from the Riau Provincial Environmental Agency, waste management operators, and community leaders. For the quantitative component, a survey was conducted with 100 respondents randomly selected from the Pekanbaru City community. The findings reveal that while supportive policies exist, field implementation remains hampered by low public participation. Statistical analysis indicates a significant correlation between the use of app-based management systems and household waste sorting efficiency (p-value < 0.05). Furthermore, the implementation of technology was found to increase waste collection reliability with an Odds Ratio (OR) of 2.4, suggesting that residents using digital platforms are over twice as likely to manage waste sustainably compared to those using conventional methods. However, lack of awareness remains a primary barrier. The study concludes that success depends on a synergistic collaboration between the government, private sector, and the public. Regular policy evaluations and infrastructure upgrades for the mobile management system are recommended to ensure responsiveness to community needs.

Keywords:
Sustainable Waste Management, Pekanbaru City, Waste Policy, Mobile Application, Public Participation, Environmental Technology.

1. Introduction

Sustainable waste management is one of the most pressing challenges in large cities, including Pekanbaru. Rapid urbanization and population growth have significantly exacerbated waste production. In Pekanbaru, data from the Environmental and Forestry Agency indicates that waste generation has reached approximately 700 to 800 tons per day, with an annual increase of 5-7% over the last three years (Riau Provincial Environmental Agency, 2022). Inadequate management practices lead to serious environmental degradation, public health risks, and a reduced quality of life (Zhang et al., 2022). This volume surge creates an urgent need for management strategies that move beyond conventional "collect-transport-dump" methods toward more integrated and sustainable systems.

Previous research has extensively discussed government initiatives and community-based waste bank programs. However, a critical research gap remains: there is a lack of empirical evidence regarding the synergy between local regulatory frameworks and the practical adoption of mobile-based digital

platforms in Pekanbaru. While existing studies focus on manual community participation (Prasetyo & Setiawan, 2022; Handayani & Hidayati, 2023)., they fail to address how digital reporting systems and real-time monitoring can overcome the logistical barriers and lack of transparency that currently hinder policy implementation in the city.

Recent studies in Southeast Asia highlight that technology is no longer optional but a necessity. In Indonesia, cities like Bandung and Jakarta have pioneered the use of applications like *e-Recycle* or *Mountrash*, which incentivize waste sorting through digital rewards. Similarly, in Vietnam and Malaysia, Geographic Information Systems (GIS) have been utilized to optimize collection routes, reducing operational costs by up to 20% (Hossain et al., 2021). These technologies, such as GIS mapping for waste hotspots and mobile apps for direct citizen reporting, provide a "bottom-up" data flow that allows governments to be more responsive. Implementing such systems in Pekanbaru could bridge the communication gap between the Riau Provincial Environmental Agency and the residents. As emphasized by Handayani and Hidayati (2023), technology-led education is more effective at fostering long-term behavioral changes than traditional outreach programs. This study aims to analyze existing management policies and the implementation of technology in Pekanbaru.

2. Method

This study employed a mixed-methods approach with an explanatory sequential design, integrating qualitative and quantitative data to provide a comprehensive analysis of waste management in Pekanbaru. The research was conducted in Pekanbaru City, focusing on three sub-districts with the highest waste production levels: Tampan, Marpoyan Damai, dan Bukit Raya. Data collection took place over a four-month period, from June to September 2023. Participants and Sampling Techniques this research is Qualitative (Key Informants): Six informants were selected using purposive sampling based on their direct involvement and authority in waste management. The sample size of six was determined by the principle of data saturation. The informants included: (1) Head of Waste Management at the Riau Provincial Environmental Agency Pekanbaru, (2) Two operational managers from private waste contractors, (3) One representative from the Pekanbaru Waste Bank Forum, and (4) Two community leaders actively managing local "TPS" (Temporary Disposal Sites).

Quantitative (Survey Respondents): A total of 100 respondents were selected using Stratified Random Sampling. The population was stratified by sub-district to ensure proportional representation of the urban demographic. The survey instrument was a structured questionnaire measuring four primary variables through a 5-point Likert scale: Knowledge: Measured by 10 items regarding local waste regulations and sorting categories. Attitude: Assessed through 8 items on perceptions of the urgency of sustainable management. Participation: Evaluated based on self-reported frequency of waste sorting and application usage. Interest: Measured by 5 items regarding the willingness to adopt new waste-tech platforms. To ensure Validity and Reliability, the instrument underwent Expert Judgment by two environmental health specialists and a pilot test on 30 individuals outside the main sample, resulting in a Cronbach's Alpha score of > 0.70 for all variables.

Data Collection Procedures are In-depth Interviews: Semi-structured interviews were conducted to explore policy implementation barriers. Quantitative Survey: Distributed via Google Forms and physical questionnaires to ensure reach across different age groups. Ethical Considerations: All participants signed an informed consent form. Data were anonymized to protect respondent privacy, and participation was strictly voluntary. Qualitative Analysis: Interview transcripts were analyzed using Thematic Analysis with a three-stage coding process: open coding, axial coding, and selective coding. Quantitative Analysis: Data were processed using IBM SPSS Statistics version 26. Analysis included descriptive statistics (univariate) and Bivariate Inferential Analysis (Chi-Square). The Chi-square test was applied under the assumptions that the data were independent, the cells had an expected frequency of at least 5, and the variables were categorical (nominal/ordinal).

3. Results and Discussion

3.1 Results

The findings indicate that despite the existence of policies supporting waste management, their implementation faces numerous obstacles. Key findings revealed a persistent lack of public awareness and participation, which ultimately hinders effective policy implementation. Furthermore, technological innovations, such as mobile applications, offer promising opportunities to improve the efficiency of

waste management practices. This study emphasizes the need for improved communication strategies aimed at actively engaging the community in waste management initiatives.

In-depth interviews with six key informants provided valuable insights into waste management policies in Pekanbaru. Several key themes emerged from the qualitative data analysis: 1. Existing Policies: Informants stated that despite the existence of policies supporting waste management, their implementation is often ineffective due to a lack of public awareness. Most residents are unaware of existing government programs, thus minimizing their participation in waste management. 2. The Role of Technology: Several informants recognized the potential of technology, particularly mobile applications, in increasing community engagement. They suggested that using applications to report waste-related issues could improve government responsiveness. 3. Challenges Faced: The main obstacles identified were the lack of budget for waste management programs, as well as low public awareness of the importance of good waste management. Informants also highlighted the issue of inadequate infrastructure to support effective waste management. Interviews also revealed that most respondents stated they were unaware of the government's waste management policies. Regarding community participation, only a small number of respondents were actively involved in the program; only half indicated interest in using a mobile application to report waste management issues. However, the majority believed that technology could improve waste management efficiency.

Quantitative data was collected through a survey of 100 respondents. Statistical analysis revealed the following findings:

Table 1. Respondent Demographics

Demographic Variables	Category	Frequency	Percentage (%)
Gender	Female	60	60%
	Male	40	40%
Age (Years)	18 – 25	25	25%
	26 – 40	45	45%
	41 – 60	22	22%
	> 60	8	8%
Education Level	High School or Below	30	30%
	Diploma / Bachelor's Degree	62	62%
	Postgraduate (Master/PhD)	8	8%
Occupation	Civil Servant / Private Employee	35	35%

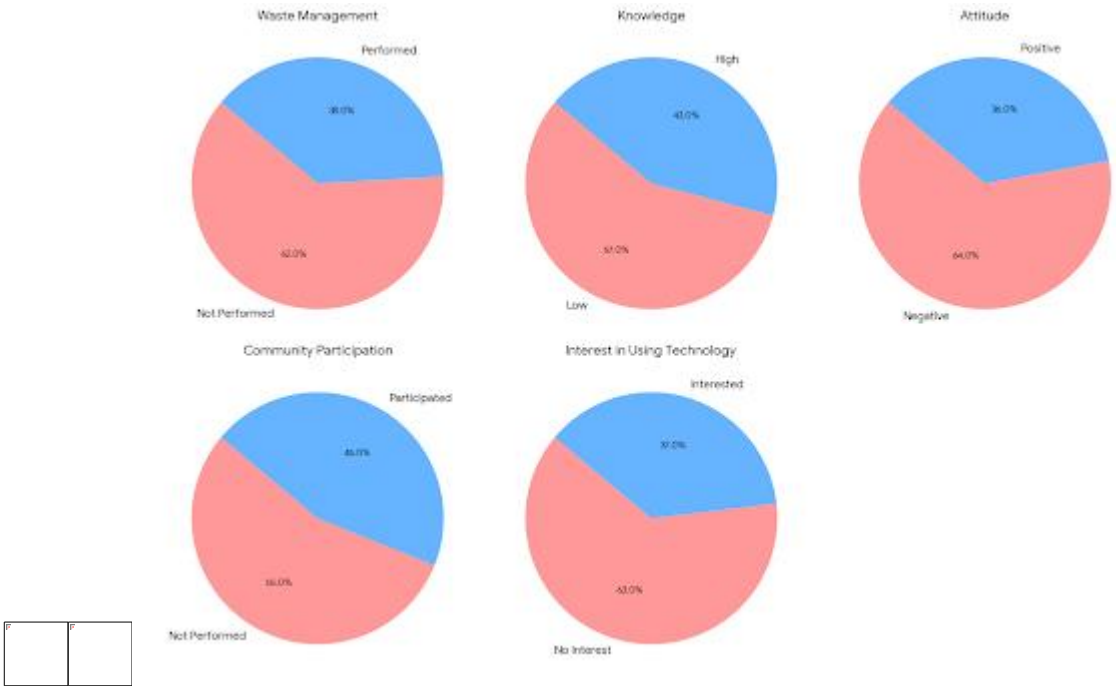
Entrepreneur / Self-employed	25	25%
Student	20	20%
Housewife / Others	20	20%

Based on Table 1, the majority of respondents were female (60%), which is consistent with previous studies suggesting that women often play a primary role in household waste management. In terms of age, 45% of respondents fall within the 26–40 age group (productive age), indicating a demographic that is typically more tech-savvy and open to mobile application-based systems. Regarding education, a significant portion of the sample (62%) holds a Bachelor's or Diploma degree, which may correlate with a higher baseline of environmental knowledge.

Table 2
Univariate Results of Independent and Dependent Variables

Variables	Frequency	Percent (%)
Dependent Variable		
Waste Management		
Not Performed	62	62
Performed	38	38
Total	100	100
Independent Variables		
1. Knowledge		
Low	57	57
High	43	43
Total	100	100
2. Attitude		
Negative	64	64
Positive	36	36
Total	100	100
3. Community Participation		
Not Performed	55	55
Participated	45	45
Total	100	100
4. Interest in Using Technology		
No Interest	63	63
Interested	37	37
Total	100	100

Figure 1
Pie Chart Independent and Dependent Variables



Waste management showed significant results, with the majority of respondents (62%) not involved in waste management, while only 38% were actively involved in such activities. In terms of knowledge, the majority of respondents (57%) had low knowledge of waste management policies, while only 43% had high knowledge. Respondents' attitudes also tended to be negative, with 64% showing less supportive attitudes towards waste management, and only 36% having positive attitudes. Regarding community participation, 55% of respondents did not participate in waste management programs, while 45% were actively involved. Finally, the majority of respondents (63%) showed no interest in using technology in waste management, while only 37% showed interest in utilizing such technology.

Table 3
Bivariate Results of the Relationship between Waste Management Knowledge

Knowledge	Waste Management						P *Value*	POR (95% CI)
	Not doing		Doing		Total			
	f	%	f	%	f	%		
Low	45	78,9	12	21,1	57	100	0,001	5,732 (2,372-13,865)
High	17	39,5	26	60,5	43	100		
Total	**62**	**62,0**	**38**	**38,0**	**100**	**100**		

Based on table 3 above,, it was found that out of 57 respondents with low knowledge, 45 (78.9%) did not manage waste. Meanwhile, out of 43 respondents with high knowledge, 17 (39.5%) respondents did not manage waste. The results of the statistical test obtained a P value of 0.001 (≤ 0.05), so it can be concluded that there is a relationship between knowledge and waste management. The POR value obtained (95% CI) = 5.732 (2.372-13.865) means that respondents with low knowledge are 5.7 times more likely to not manage waste than respondents with high knowledge.

Table 4
Bivariate Results of the Relationship between Attitudes and Waste Management

Attitude	Waste Management						P *Value*	POR (95% CI)
	Not doing		Doing		Total			
	F	%	f	%	f	%		
Negative	51	79,7	13	20,3	64	100	0,001	8,916 (3,608-22,705)
Positive	11	30,6	25	69,4	36	100		
Total	**62**	**62,0**	**38**	**38,0**	**100**	**100**		

Based on table 4 above,, it was found that out of 64 respondents with negative attitudes, 51 (79.7%) did not manage waste. Meanwhile, out of 36 respondents with positive attitudes, 11 (30.6%) respondents did not manage waste. The results of the statistical test obtained a P value of 0.0001 (≤ 0.05), so it can be concluded that there is a relationship between attitudes and waste management. The POR value obtained (95% CI) = 8.916 (3.608-22.705) means that respondents with negative attitudes are 8.9 times more likely to not manage waste than respondents with positive attitudes.

Table 5
Bivariate Results of the Relationship between Community Participation and Waste Management

Public Participation	Waste Management						P *Value*	POR (95% CI)
	Not doing		Doing		Total			
	f	%	f	%	f	%		
Public Participation	41	74,5	14	25,5	55	100	0,008	3,347 (1,440-7,778)
Not Participating	21	46,7	24	53,3	45	100		
Total	**62**	**62,0**	**38**	**38,0**	**100**	**100**		

Based on table 5 above, it was found that out of 55 respondents who did not participate, 41 (74.5%) did not manage waste. Meanwhile, out of 45 respondents who participated, 21 (46.7%) respondents did not manage waste. The results of the statistical test obtained a P value of 0.008 (≤ 0.05), so it can be concluded that there is a relationship between community participation and waste management. The POR value obtained (95% CI) = 3.347 (1.440-7.778, meaning that respondents who did not participate were 3.3 times more likely to not manage waste than respondents who participated.

Table 6
Bivariate Results of the Relationship between Community Interest and Waste Management

Public Interest	Waste Management						P *Value*	POR (95% CI)
	Not doing		Doing		Total			
	f	%	f	%	f	%		
No Interest	46	73,0	17	27,0	63	100	0,006	3,551 (1,509-8,358)
There is Interest	16	43,2	21	56,8	37	100		
Total	**62**	**62,0**	**38**	**38,0**	**100**	**100**		

Based on table 6 above, it was found that of the 63 respondents who had no interest, 46 (73.0%) did not carry out waste management. Meanwhile, of the 37 respondents who had interest, 16 (43.2%) respondents did not carry out waste management. The results of the statistical test obtained a P value of 0.006 (≤ 0.05), so it can be concluded that there is a relationship between community interest and waste management. The POR value obtained (95% CI) = 3.551 (1.509-8.358) means that respondents who had no interest were 3.5 times more likely to not carry out waste management than respondents who had interest.

3.2 Discussion

Effective waste management is a major challenge in various cities, including Pekanbaru. This study aims to explore the implementation of waste management policies and explore the factors influencing public participation in these programs (Kartini & Zulkarnaini, 2025). Although policies supporting waste management exist in Pekanbaru, their implementation has been ineffective due to a lack of public awareness and participation (Handayani & Agussalim, 2023). Technological innovation, especially mobile applications, offers great potential to increase efficiency and community engagement in waste management (Alavi et al., 2022). Lack of budget, low public awareness, and inadequate infrastructure are the main challenges to effective waste management (Zainudin et al., 2021). Low knowledge, negative attitudes, and lack of community participation are significantly related to poor waste management (Afdal & Yuliawati, 2020)

Qualitative research results show that most people are unaware of the waste management policies implemented by the government. This leads to minimal active community participation in waste management programs. Effective outreach is crucial to raise public awareness about the importance of waste management and how they can actively participate. The government needs to develop a communication strategy that is targeted and easily understood by the public (Widiastuti & Raharjo, 2021).

Several informants recognized the potential of technology, especially mobile applications, in increasing community engagement. Applications can be used to report waste-related issues, provide information on collection schedules, and provide information on waste management schedules. waste management, and provide education on proper waste management. Surveys show that half of respondents are interested in using mobile applications to report waste management issues, and the majority believe that technology can improve waste management efficiency. The development and implementation of mobile waste management applications need to be prioritized. Applications must be easy to use, informative, and responsive to community needs (Khoshgoftar & Zare, 2023). The government needs to allocate an adequate budget for waste management programs, increase public awareness through education and campaigns, and improve waste management infrastructure (Setiawan & Indriani, 2022). Increasing knowledge, changing attitudes, increasing community participation, and increasing interest in using technology are key to improving the effectiveness of waste management (Khosravi & Shafiee, 2022).

The quantitative findings of this study indicate that Attitude is the strongest predictor of waste management behavior in Pekanbaru, with an Odds Ratio (OR) of 8.916. Theoretically, this aligns with the Theory of Planned Behavior (TPB), which posits that an individual's attitude toward a behavior is the primary foundation for forming intentions and subsequent actions. Respondents with a positive perception of environmental sustainability are nearly nine times more likely to practice proper waste management than those with an apathetic attitude. The practical implication is that policy-making in Pekanbaru must not focus solely on physical infrastructure. The high OR value suggests the presence of "unactivated intentions." Compared to studies in Bandung (Prasetyo & Setiawan, 2022), where the primary constraint is limited land for disposal sites, the main challenge in Pekanbaru is socio-psychological. Residents tend to perceive waste as the sole responsibility of the government once retribution fees are paid.

The utilization of mobile applications in Pekanbaru faces unique contextual challenges. Although technology is viewed as a potential solution (Alavi et al., 2022), there remains a gap between interest and actual usage. Unlike Jakarta, which has successfully integrated reporting apps with rapid response units, the challenge in Pekanbaru lies in the limited back-end infrastructure supporting the application. Implementation challenges include: Digital Literacy: Disparities in smartphone proficiency across different age groups. Trust in System**:** Concerns that reporting via an app will not result in tangible

physical action by field officers.Development and Implementation of Mobile Applications by developing mobile applications that are easy to use, informative, and responsive to community needs. Mobile applications can increase community participation in waste management (Khoshgoftar & Zare, 2023), providing waste problem reporting features, waste collection schedule information, and waste management education within the application. Interactive features in the application can help the public report waste management problems (Li et al., 2020), providing incentives for people who actively use the application. Incentives can encourage community involvement in the use of waste management applications (Fadli & Suwarno, 2021) . Improving Budget and Infrastructure, by allocating an adequate budget for waste management programs. Appropriate budget allocation is crucial for the success of waste management programs (Kurniawan & Hartono, 2022).

Improve and update waste management infrastructure, such as waste collection sites, garbage trucks, and waste processing facilities. Good infrastructure supports efficiency in waste management (Rahman & Zaman, 2021), Increasing Community Participation by involving the community in the planning and implementation of waste management programs. Active community participation can increase the effectiveness of waste management programs (Tadesse & Belayneh, 2023), forming community groups that care about waste management. Community groups can become agents of change in waste management, giving awards to individuals or groups who excel in waste management. Rewards can motivate the community to contribute more to waste management (Khosravi & Shafiee, 2022). Utilizing Technology by implementing automated waste sorting technology to increase efficiency. Automation technology can reduce human error in waste sorting (Alavi et al., 2022), utilizing technology to process waste into energy (biogas) or other economically valuable products. Processing waste into energy can provide a sustainable solution (Pahlavan & Rahman, 2023), using smart sensors to monitor waste volume and optimize waste collection routes. Smart sensors can help in more efficient management. Strengthening Policies and Regulations by creating specific regional regulations regarding household waste management. Clear regulations are crucial to ensure effective waste management (Kurniawan et al., 2022), enforcing laws against violations related to waste management. Law enforcement can provide a deterrent effect for violators (Rahman & Zaman, 2021), and providing incentives for companies or individuals who invest in waste management technology. Incentives can attract investment in waste management technologies (Hossain et al., 2021).

Contextually, the local culture in Pekanbaru which relies heavily on third-party (private) services for waste collection creates a distance between the waste generator and the management process. Compared to Surabaya, which highlights community strength through "Environmental Cadres," Pekanbaru still relies heavily on top-down approaches. In Southeast Asia, similar cases are observed in Hanoi, where rapid urbanization often outpaces the community's technological adaptation (Hossain et al., 2021). The success of technology in Pekanbaru requires synchronization between regional policies and local habits that are more responsive to direct incentives.

This study has several limitations that should be considered: Methodological Limitation: The use of a cross-sectional method only provides a snapshot in time and cannot capture long-term behavioral changes following technological intervention. Sampling Limitation: The sample of 100 respondents, while statistically significant, may not fully represent the socio-economic diversity of Pekanbaru's peripheral areas. Self-Report Bias: There is a possibility of bias where respondents provide "socially desirable" or normative answers in the questionnaire, which may differ from their daily practices.

4. Conclusion

This study concludes that while Pekanbaru City has established regulatory frameworks for waste management, their field implementation remains suboptimal due to significant socio-psychological barriers. The quantitative analysis confirms that knowledge, attitude, and participation are critical determinants of waste management behavior. Notably, attitude emerged as the strongest predictor with an Odds Ratio (OR) of 8.916, indicating that individuals with a positive perception of environmental responsibility are nearly nine times more likely to engage in sustainable waste practices. Furthermore, the research highlights a "digital gap" where, despite the significant potential of mobile applications to improve efficiency ($p < 0.05$), public interest remains low (63%) due to limited digital literacy and a lack of trust in the government's back-end responsiveness.

In summary, the transition to sustainable waste management in Pekanbaru requires more than technical infrastructure; it demands a fundamental shift in public disposition and a reliable integration between digital platforms and physical waste services. Recommendations 1. Practical Implications for Stakeholders. For the Pekanbaru City Government: Shift the communication strategy from technical instructions to "attitude-based" campaigns that emphasize the economic and health benefits of waste sorting to leverage the high OR found in this study. Develop an integrated "Command Center" that connects the mobile application directly with GPS-tracked collection trucks to build public trust through real-time responsiveness. For the Community: Establish "Digital Waste Pioneers" at the neighborhood level (RT/RW) to assist older demographics in navigating waste management technology. Active participation in community-based waste banks should be incentivized through digital rewards that can be converted into electricity tokens or retribution discounts. For the Private Sector: Collaborate with the government to provide the necessary infrastructure for technology-based sorting and processing, such as smart-bins and automated collection systems. Suggestions for Future Research; Experimental Studies: Future researchers should conduct randomized controlled trials (RCTs) to test the actual effectiveness of specific mobile application features (e.g., gamification vs. cash incentives) in increasing sorting rates ; Longitudinal Research: Conduct a multi-year longitudinal study to track behavioral changes in Pekanbaru's residents as digital literacy and infrastructure improve over time ; Qualitative Depth: Further exploration into the "Resistance to Technology" through ethnographic studies to understand the deep-seated cultural factors behind low digital interest in certain sub-districts.

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