

Technological Innovation and Waste Management Behaviour: A Sustainable Development Perspective

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Abstract : The study investigates the impact of technological adaptation on the Solid Waste Management behaviour among the people of Imphal city, Manipur. Data for the study was gathered using a standardised questionnaire, which was distributed through various means such as emails, Whatsapp etc. A sample size of 75 respondents was selected using simple random method. The analytical framework used IBM SPSS 21 software, employing statistical tools such as KMO (Kaiser-Meyer-Olkin), Baret's test, Cronbach's Alpha reliability test, and Regression analysis. The study provides practical insights to the policy makers, technology developers, academic researcher etc. Future researcher avenues include integrating cultural factors and its impact on Solid Waste Management (SWM) behaviour among the respondents.

Keywords: *Solid Waste Management, technological adoption, solid waste, sustainable development, public participation.*

I. INTRODUCTION

Waste management goes beyond the current times and indeed has a historical evolution since the establishment of ancient civilisations such as the ancient Rome and Greece for example; it was only towards the late 18th century that first municipal collection of garbage began in some states of United States of America. A technological approach to waste management developed only in the late 19th century but most of the cities still depended on more convenient handling of waste system rather than proper disposal (Jerry, 2026). Since the last few decades, solid waste management system has evolved controversially complex and multifaceted commitments between technological alternatives, economic instruments, and regulatory frameworks (Kaza et al., 2018; Petts, 2001).

Urban areas are growing faster in less Economically Develop Countries (LEDCs) than anywhere else in the world, along with such growth comes problems and challenges which requires proper planning and management (Henderson & Turner, 2020). The study area Imphal being the capital of Manipur, a state in the Northeast of India faces the challenges of proper solid waste management as well. According to official document released by the government of Manipur on 4th December 2024 we can examine that as compare to other major city in the country Imphal has relatively less numbers of industries and factories which means lesser amount of waste generated by them. Ultimately making the urban population the major generator of solid waste in the city. Here the main objective of the study is to investigate whether service-based technologies at hand has any significant impact on solid waste management behaviour among the population of the city, taking in the importance of Technological Innovation (TI) at hand which is again according to Wikipedia is an extended concept of Innovation, here innovation refers to adding extra steps to developing new services and products in the marketplace or in the public that fulfil unaddressed needs or solve problems that were not in the past.

The study adapts one of the three integrated factor approach to Sustainable Waste Management given by Visvanathan et al. (2004), that is involvement and participation of all stakeholders: waste producers, waste processors and government institutions however here we will only be focusing only on public participation as the primary source of solid waste management through service-based technology usage.

II. REVIEW OF LITERATURE

Aditee Potdar et al. (2016) examines how the Clean Development Mechanism (CDM) can promote innovation in Solid Waste Management (SWM) in developing countries. The paper begins by explaining that rapid population growth and urbanization in developing countries have significantly increased solid waste generation, creating major environmental and public health challenges. The study highlights several innovative technologies adopted through CDM projects and their benefit for sustainable urban development.

Ava Heidari et al. (2018) investigates the main objective of the paper explaining youth waste management behaviour, especially source separation of waste, using an extended Theory of Planned Behaviour (TPB) model combined with Structural Equation Modelling (SEM). The authors highlight that increasing urbanization have led to a rapid rise in solid waste generation, making recycling and waste separation at the source essential strategies for sustainable waste management. The study concludes that youth sustainable waste management behaviour is strongly influenced by psychological factors, the integration of SEM demonstrates that enhancing internal motivation and social responsibility can significantly improve sustainable waste practices among young people.

Clairvair O. Squires (2006) investigates the role of public participation in Solid Waste Management in Small Island Developing States (SIDS) and to assess low community involvement influences the effectiveness and sustainability of waste management systems in the vulnerable regions. The study draws attention to the challenges due to limited land, fragile ecosystems and high

waste generation, SIDS require strong public engagement for sustainable waste practices. The author conclude that environmental education and better management strategies are key to achieving sustainable Solid Waste Management in SIDS.

Joseph Zamchinlian Tungnung and Subhash Anand (2017) investigates the pattern of urban sprawl and Land Use and Land Cover change in Imphal over a long-term period (1970-2015), specifically focusing on how population growth and migration gave reshaped the spatial structure of Imphal city and its peripheral areas. Major findings include rapid built-up in area, decline of agricultural land stating the key drivers of urban sprawl in Imphal, highlighting that without proper urban planning, the city continues expanding uncontrollably toward the fringe region, posing a serious environmental problems and unmanaged urban growth.

Lilliana Abarca Guerrero et al. (2013) reviews the major challenges faced by cities in developing countries in managing solid waste, based on analysis of literature, field observations, stakeholder workshops, and data from over 30 urban areas across 22 developing countries. Where the authors identify several challenges such as rapid increase in waste generation, financial constrain, lack of understanding, poor coordination, governance challenges and lack of data. Therefore, concluding a need for more integrated planning and coordination.

Mukisa Philemon Kirunda (2009) examines the role of public participation in Solid Waste Management and to identify the major challenges and future prospects for improving community involvement in waste management systems, especially in developing urban contexts. The authors argue that effective Solid Waste Management cannot be achieved through government efforts alone and requires active participation from households and communities. Mukisa et al. conclude that Sustainable Solid Waste Management largely depends on active public participation, and effective governance.

Raazia Saher et al. (2023) proposes a Holistic Waste Collection Model (HCTS) that combines human participation and digital technology to make waste management more efficient and sustainable. The authors argue that traditional waste management systems are inefficient and has low public involvement. The core idea is that technology alone is not enough for an effective waste management, it requires collaboration between citizens, agencies and smart systems, the study also highlights several issues and concludes that integrating technology with human collaboration can significantly improve waste management system.

Sumana Jagadeshi Raghu and Lewlyn L. R. Rodrigues (2020) reviews systematically mapping behavioural research on solid waste management across 80 peer-reviewed studies published between 1968 and 2020. The authors identified a strong bias toward high-income nations (61% of studies, with USA contributing 44%) and a focus on recycling that largely applied individual-behaviour theories, where the Theory of Planned Behaviour (TPB) being the most frequently tested. The most common psychological construct were attitude, intention, perceived behavioural control, subjective and social norms, and environmental knowledge. The authors highlight four research gaps. Implications stress the need for more interdisciplinary and evaluation-focused research, the incorporation of social-practice and technology adoption frameworks, and evidence-based policy development to promote pro-environmental waste-handling behaviours worldwide.

OBJECTIVE OF THE STUDY

- To examine the impact of technological innovation on solid waste management behaviour of people of Manipur.

HYPOTHESIS OF THE STUDY

H_0 : Technological innovation does not have a significant impact on solid waste management behaviour.

III. RESEARCH METHODOLOGY

The study adopted a quantitative research design based on primary data collected through a structured and standardized questionnaire from Meys et al. (2020) and Akkalatham and Taghipour (2021) from a sample size of 120 respondents selected using simple random sampling method from Imphal area. The questionnaire was administered using a Google Form and distributed to respondents via email and WhatsApp. The study focused on two main variables: Solid Waste Management Behaviour (SWMB) and Technological Innovation (TI). SWMB was measured using four items (SWMB1, SWMB2, SWMB3, and SWMB4), while Technological Innovation was measured using six items (TI1, TI2, TI3, TI4, TI5, and TI6).

For data analysis, SPSS version 21 was used to conduct various statistical techniques, including descriptive analysis, Kaiser-Meyer-Olkin (KMO) and Bartlett's test to assess sampling adequacy, Cronbach's alpha to test reliability, factor analysis to examine construct validity, and regression analysis to determine the impact of technological innovation on solid waste management behaviour.

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IV. DATA ANALYSIS AND INTERPRETATION

Table 1: Demographic profile of the respondents

Particulars		Frequency	Percentage
Gender	Male	37	49.33
	Female	38	50.67
	Total	75	100
Age	18-22	34	45.33
	23-29	35	46.67
	30-39	4	5.33
	40 & above	2	2.67
	Total	75	100
Educational Qualification	Class XII	1	1.33
	Graduation	38	50.67
	Post-graduation & above	36	48.00
	Total	75	100
Monthly Income	Less than 10,000	59	78.66
	10,001-20,000	8	10.67
	20,001-30,000	3	4
	More than 30,000	5	6.66
	Total	75	100
Marital Status	Married	5	6.66
	Unmarried	70	93.34
	Total	75	100

Source: Author's Calculation (Primary Data)

Table 1 shows the demographic profile of the respondents. The sample comprised 75 participants with equal representation of males (49.33%) and females (50.67%), indicating a balanced gender distribution. In terms of age, the majority of respondents were in the 23–29 years category (46.67%), closely followed by those aged 18–22 years (45.33%), while only a small proportion belonged to the 30–39 years (5.33%) and 40 years and above (2.67%) groups. Regarding educational qualification, most respondents were graduates (50.67%) and postgraduates or above (48%), with very few having completed only Class XII (1.33%). In terms of monthly income, a significant majority (78.66%) earned less than ₹10,000, whereas smaller percentages were distributed across higher income categories.

Table 2: KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.768
Bartlett's Test of Sphericity	Approx. Chi-Square	484.747
	df	45
	Sig.	0.000

Source: Author's Calculation (Primary Data)

Table 2 shows the results of the KMO and Bartlett's Test conducted to assess the suitability of the data for factor analysis. The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy is 0.768, which exceeds the recommended threshold of 0.60, indicating that the sample size is adequate and the data are appropriate for factor analysis. Additionally, Bartlett's Test of Sphericity is statistically significant ($\chi^2 = 484.747$, $df = 45$, $p < 0.001$), suggesting that the correlation matrix is not an identity matrix and that there are significant relationships among the variables. Therefore, the results confirm that the data are suitable for proceeding with factor analysis.

Table 3: Reliability Statistics

Cronbach's Alpha	N of Items
0.857	10

Source: Author's Calculation (Primary Data)

Table 3 shows the reliability statistics of the scale used in the study. The Cronbach's Alpha value is 0.857 for the 10 items, which exceeds the recommended threshold of 0.70, indicating high internal consistency among the items. This suggests that the items are reliably measuring the same underlying construct and that the scale is suitable for further analysis.

Table 4: Factor Analysis

Variables	Solid Waste Management Behaviour	Technological Innovation
SWMB1	0.848	
SWMB2	0.617	
SWMB3	0.730	
SWMB4	0.799	
TI1		0.616
TI2		0.819
TI3		0.613
TI4		0.720
TI5		0.837
TI6		0.866

Source: Author's Calculation (Primary Data)

Table 4 presents the factor loadings of the items done using varimax rotation under Solid Waste Management Behaviour (SWMB) and Technological Innovation (TI). All items show satisfactory loadings on their respective constructs, with values above the commonly accepted threshold of 0.60. For SWMB, the loadings range from 0.617 to 0.848, indicating strong representation of the construct, with SWMB1 showing the highest loading (0.848). Similarly, for TI, the loadings range from 0.613 to 0.866, with TI6 (0.866) and TI5 (0.837) demonstrating particularly strong contributions. Since all items load significantly on their intended factors, the results confirm good convergent validity and support the adequacy of the measurement model.

Table 5: Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	0.621 ^a	0.385	0.377	3.18003	0.385	45.730	1	73	0.000
a. Predictors: (Constant), TI									

Source: Author's Calculation (Primary Data)

Table 5 shows the model summary of the regression analysis between technological innovation (TI) and the dependent variable. The results indicate a moderate positive relationship ($R = 0.621$). The model explains 38.5% of the variance in the dependent variable ($R^2 = 0.385$), and the adjusted R^2 value of 0.377 confirms satisfactory explanatory power. The overall model is statistically significant ($F = 45.730$, $p < 0.001$), indicating that technological innovation has a significant effect on the dependent variable.

Table 6: ANOVA table

Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	462.448	1	462.448	45.730	0.000 ^b
	Residual	738.219	73	10.113		
	Total	1200.667	74			
a. Dependent Variable: SWMB						
b. Predictors: (Constant), TI						

Source: Author's Calculation (Primary Data)

Table 6 represents the result of ANOVA results indicate that the regression model is statistically significant ($F = 45.730$, $p < 0.001$). The regression sum of squares (462.448) compared to the residual sum of squares (738.219) shows that a substantial portion of the total variation in SWMB is explained by TI. This confirms that TI significantly predicts SWMB and that the overall model provides a good fit to the data.

Table 7: Coefficients

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	2.680	1.078		2.486	0.015		
	TI	0.485	0.072	0.621	6.762	0.000	1.000	1.000
a. Dependent Variable: SWMB								

Source: Author's Calculation (Primary Data)

The coefficients table shows that technological innovation (TI) has a positive and statistically significant effect on solid waste management behaviour (SWMB) ($B = 0.485$, $\beta = 0.621$, $t = 6.762$, $p < 0.001$). The collinearity statistics (Tolerance = 1.000, VIF = 1.000) indicate that there is no multicollinearity issue in the model, ensuring the reliability of the regression estimates. The unstandardized coefficient suggests that a one-unit increase in TI leads to a 0.485 unit increase in SWMB, while the standardized beta value ($\beta = 0.621$) reflects a strong positive influence. Since the p-value is less than 0.05, the null hypothesis stating that technological innovation does not have a significant relationship with solid waste management behaviour is rejected. Therefore, it can be concluded that technological innovation significantly influences solid waste management behaviour.

Table 8: Result of Hypothesis testing

Hypothesis	Path diagram	B	t	p-value	Result
H ₀ 1:	TI → SWMB	0.621	0.6762	0.000	Rejected

Source: Author's Calculation (Primary Data)

The hypothesis testing results indicate that technological innovation (TI) has a positive and statistically significant effect on solid waste management behaviour (SWMB). The standardized beta coefficient ($\beta = 0.621$) shows a strong positive relationship between TI and SWMB. Since the p-value (0.000) is less than 0.05, the result is statistically significant. Therefore, the null hypothesis (H₀), which states that technological innovation does not have a significant relationship with solid waste management behaviour is rejected. This confirms that Technological Innovation (TI) significantly influences solid waste management behaviour.

V.DISCUSSION, IMPLICATIONS AND CONCLUSION

5.1. Discussion

The findings reveal that technological innovation has a strong and significant positive influence on solid waste management behaviour, explaining a substantial proportion of its variation and confirming the rejection of the null hypothesis. The absence of

multicollinearity further strengthens the reliability of the results. These findings are consistent with earlier studies, as Zhang et al. (2019) reported that technological advancements improve waste segregation and recycling efficiency, Guerrero et al. (2013) emphasized that improved waste management technologies enhance sustainability and system effectiveness, and Awasthi et al. (2021) highlighted that smart waste management systems and digital tools promote pro-environmental behaviour. Together, these studies support the present results and reinforce the role of technological innovation in improving solid waste management behaviour.

5.2. Implications of the Study

The study has important practical, policy, theoretical, and social implications. It highlights that technological innovation significantly enhances solid waste management behaviour, suggesting that policymakers and municipal authorities should invest in modern waste management technologies such as smart systems and digital monitoring tools. The findings support the integration of innovation-driven strategies into environmental policies and urban planning frameworks. The study also contributes to existing literature by empirically validating the role of technological innovation as a key determinant of sustainable environmental behaviour.

5.3. Limitations and future research direction

The study is limited by its relatively small and geographically confined sample, which may restrict the generalizability of the findings. Moreover, it examined only technological innovation as a predictor of solid waste management behaviour, without considering other potential influencing factors. Future research may employ larger and more diverse samples, include additional variables to develop a more comprehensive model, and undertake longitudinal or comparative studies to gain deeper insights into the determinants of solid waste management behaviour.

5.4. Conclusion

In conclusion, the study establishes that technological innovation plays a significant and positive role in influencing solid waste management behaviour. The findings confirm that advancements in technology contribute meaningfully to improved waste management practices and environmental responsibility. Supported by previous empirical studies, the results reinforce the importance of integrating innovative technologies to enhance sustainability and promote effective solid waste management behaviour.

REFERENCES

- [1] Akkalatham W and Taghipour A. (2021). Pro-environmental behavior model creating circular economy in steel recycling market, empirical study in Thailand. *Env Chall* 2021; 4: 100112.
- [2] Awasthi, A. K., Li, J., Koh, L., & Ogunseitan, O. A. (2021). Circular economy and electronic waste management: A review of regulatory approaches and technological innovations. *Journal of Cleaner Production*, 290, 125–138. <https://doi.org/10.1016/j.jclepro.2020.125138>.
- [3] Guerrero, L. A., Maas, G., & Hogland, W. (2013). Solid waste management challenges for cities in developing countries. *Waste Management*, 33(1), 220–232. <https://doi.org/10.1016/j.wasman.2012.09.008>
- [4] Heidari, A., Kolahi, M., Behraves, N., Ghorbanyon, M., Ehsanmansh, F., Hashemolhosini, N., & Zanganeh, F. (2018). Youth and sustainable waste management: a SEM approach and extended theory of planned behavior. *Journal of Material Cycles and Waste Management*, 20(4), 2041-2053.
- [5] Kirunda, M. P. (2009). Public Participation in Solid Waste Management: Challenges and Prospects. A case of Kira Town Council, Uganda. Retrieved July, 10, 2015.
- [6] MeysR, FrickF, Westhues S, et al. (2020). Towards a circular economy for plastic packaging wastes the environmental potential of chemical recycling. *Resour Conserv Recycl* 2020; 162: 105010.
- [7] Potdar, A., Singh, A., Unnikrishnan, S., Naik, N., Naik, M., Nimkar, I., & Patil, V. (2016). Innovation in solid waste management through clean development mechanism in developing countries. *Procedia Environmental Sciences*, 35, 193-200.
- [8] Sumana Jagadeshi Raghu & Lewlyn L.R. Rodrigues (2020) Behavioral aspects of solid waste management: A systematic review, *Journal of the Air & Waste Management Association*, 70:12, 1268-1302, DOI: 10.1080/10962247.2020.1823524
- [9] Saher, R., Saleh, M., & Anjum, M. (2023). Holistic trash collection system integrating human collaboration with technology. *Applied Sciences*, 13(20), 11263.
- [10] Squires, C. O. (2006). Public participation in solid waste management in small island developing states. *Caribbean Development Bank, Barbados*.
- [11] Tunngung, J. Z., & Anand, S. (2017). Dynamics of urban sprawl and landuse change in Imphal of Manipur, India. *Space and Culture, India*, 5(2), 69-83.
- [12] Zhang, D., Huang, G., Yin, X., & Gong, Q. (2015). Residents' waste separation behaviors at the source: Using SEM with the theory of planned behavior in Guangzhou, China. *International Journal of Environmental Research and Public Health*, 12(8), 9475–9491. <https://doi.org/10.3390/ijerph120809475>

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