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Multivariate Assessment of Socioeconomic Determinants Influencing Informal E-Waste Recycling Practices in Bhavnagar, Gujarat

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ABSTRACT

The paper examines the issue of socio-economic factors influencing involvement in informal e-waste recycling in Bhavnagar, Gujarat, through four aspects: income, level of education, household size, and access to infrastructure. The responses were collected from 120 respondents through a cross-sectional survey, and the data were analysed through descriptive statistics, bivariate analysis, principal component analysis (PCA), factor analysis, and multivariate logistic regression. The demographic data indicated that the majority, 60%, were women, 50% were married, and 40% had a secondary education. Regarding income, half of the respondents earned between 5,000 and 10,000 rupees, and 40% depended on e-waste as their core source of income. The bivariate analysis revealed a moderate positive correlation between average hours worked and income ($r = 0.45$, $p = 0.02$). The ANOVA test revealed a significant difference in the number of dependents across income levels ($F = 6.5$, $p = 0.003$). As shown by PCA, the first component (Socioeconomic factors) accounted for 35% of the variance. The logistic regression model revealed that the high-income categories (10,001-20,000 and >20,000 rupees) had significantly higher likelihoods of possessing toilets (odds ratio 1.00, $p = 0.004$ and 1.50, $p = 0.003$, respectively). The effect of income and access to electricity was not statistically significant ($\beta = 0.30$, $p = 0.095$). These findings underscore the significance of socio-economic factors and infrastructure in enhancing access to sanitation and improving the well-being of workers.

Keywords: E-waste recycling, socio-economic factors, sanitation access, household income, multivariate logistic regression.

A. Introduction

The recent economic doomsday in terms of electronic waste (e-waste) production has been revealed to be one of the most challenging and fastest-rising waste management issues of the 21st century. The Geem was supported by the Global E-Waste Monitor (2024) and reported that around 62 million metric tons of e-waste were produced globally in 2023, with only 20% formally recovered through recycling. The rest ends up in households as surplus or in informal systems, which often operate under haphazard conditions and are frequently hazardous to the environment (Blade et al., 2024a, b). In emerging nations such as India, information inadequacy in addressing the informal recycling of e-waste is not only due to regulatory and infrastructural weaknesses, but also to the informal survival mechanisms of the marginalised urban poor. Typical of many informal economic activities, Bhavnagar, situated in Gujarat, features electronics waste collection and disassembly, as well as basic forms of recycling (Dutta & Goel, 2021; Islam, 2021). It is essential to note that the Alang area has been joined by other nearby activities involving ship-breaking, which has further exacerbated the importation of complex, metal-inclusive structures. This has led to the establishment of another parallel, unofficial channel of e-waste recyclers that are not covered by legal provisions. The informal e-waste industry in Bhavnagar continues to operate, marred by environmental and health risks, as social and economic factors, including poverty, a lack of formal job opportunities, low education, and informal labour structures, contribute to the field's attractiveness.

The available literature suggests that a complex combination of social and economic factors often promotes the informal recycling of e-waste. According to Ongondo et al. (2022), informal recycling is more prevalent among low-income earners, migrants, and individuals from marginalised castes because they have minimal access to formal employment. Furthermore, Sthiannopkao and Wong (2013) and Isangadighi et al. (2025) highlighted that educational status, family size, and gender are key factors predicting risk-taking behaviour in informal waste processing. Although several studies on the informal recycling of e-waste have been conducted at the national level, there is a significant deficiency of studies at the micro level, especially in suburban and mid-sized cities, such as Bhavnagar, where the informal recycling of e-waste is becoming increasingly normalised but remains less studied. The perceived lack of knowledge regarding the socioeconomic factors influencing participation in informal e-waste recycling in Bhavnagar prompted the current research to evaluate the following research objective. Through a multivariate analytical model, the researcher will examine how age, education, income, household size, duration of residence, and gender influence participation in the informal recycling industry. The research

method employs a structured questionnaire and an observational checklist to collect primary information from the selected respondents in the major recycling hotspots of the city.

The reason to use multivariate analysis is based on the necessity to deconfound the overlapping and interacting effects of these variables. In contrast to bivariate techniques, multivariate techniques provide a powerful method for isolating the characteristic impact of one socioeconomic factor while controlling for others. Following this direction has been common in recent empirical studies in informal economies (Adama, 2021; Isangadighi & Udeh, 2023; Chowdhury et al., 2023). Ultimately, the research will yield actionable knowledge that can be applied in designing inclusive policy actions, promoting safer recycling practices, and providing avenues for integrating the informal e-waste sector into formal industrial governance processes in Gujarat. Through the identification of essential socioeconomic predictors, the study can inform localised waste management planning as well as the broader debate on achieving a sustainable urban livelihood in the Global South.

B. Methodology

The socioeconomic determinants affecting the activities of informal e-waste recycling were also measured in Bhavnagar, Gujarat, using a cross-sectional survey design, as reported in this study. Due to its location, the study area, Bhavnagar, is surrounded by informal recycling activities, as it is the nearest port to the Alang Ship-Breaking Yard and also home to low-income settlements. The sample consisted of individuals living in clusters where informal recycling is a standard practice. They were selected purposively as those engaged in the informal handling of e-wastes, including scavengers, sorters, dismantlers, and traders. Cochran was used to establish a sample size of 120 at a 95% confidence level and a 0.09 margin of error. Data was collected through two study tools: a structured questionnaire and an observational checklist. The questionnaire included questions on demographic characteristics, socioeconomic status, type of e-waste participation, and risk awareness and attitudes. It was pre-tested and validated based on Cronbach's alpha ($\alpha = 0.75$). Field conditions, that is, tools used during work, site safety, and exposure to hazards, were recorded on the checklist and specifically constituted a secondary verification measure of self-reported data.

SPSS v27 was used to analyse the data. A data summary was conducted using descriptive statistics (frequencies, means, and standard deviations), and associations were evaluated using bivariate analysis (Chi-square tests and t-tests). To achieve a deeper, multi-faceted analysis, a Principal Component Analysis (PCA) was conducted to reduce the dimensionality and develop indices (deprivation index) that were subsequently used as predictors. The socioeconomic variables (age, gender, education, income, caste, household size, and residence type) were considered as independent variables, and participation in informal e-waste recycling was used as the dependent variable in a multivariate logistic regression analysis. The interaction of terms (gender × education, income × household size) was also tested to examine moderating effects. The diagnostics considered as the model were H-L goodness-of-fit, the Nagelkerke R-squared, and predictive validity as measured by the ROC curve and AUC. There was also a program to conduct hierarchical cluster analysis to profile the recyclers (high-risk, opportunistic, poverty-driven). A qualified review board approved it. All respondents gave informed consent, and the provisions on confidentiality and anonymity were adhered to by following the ICMR (2017) ethics standards.

C. Results

Table 1: Socio-Demographic Profile of Respondents

Variable	Response Option	Frequency (n)	Percentage (%)
Gender	Male	48	40%
	Female	72	60%
	Other	0	0%
Marital Status	Single	36	30%
	Married	60	50%
	Divorced	18	15%
	Widowed	6	5%
Educational Level	No schooling	0	0%
	Primary	36	30%
	Secondary	48	40%
	Higher Secondary	24	20%

Variable	Response Option	Frequency (n)	Percentage (%)
	Graduate	12	10%
	Illiterate	0	0%
Literacy Level	Can read only	36	30%
	Can read and write	84	70%
	Native	72	60%
Migration Status	Internal migrant	36	30%
	Cross-state migrant	12	10%
	Permanent	36	30%
Type of Housing	Semi-permanent	72	60%
	Temporary	12	10%
	Yes	108	90%
Access to Electricity	No	12	10%

Table 2: Socioeconomic Status of the Respondents

Variable	Response Option	Frequency (n)	Percentage (%)
Monthly Household Income	<₹5,000	36	30%
	₹5,000–₹10,000	60	50%
	₹10,001–₹20,000	12	10%
	>₹20,000	12	10%
Primary Source of Income	E-waste	48	40%
	Casual Labour	36	30%
	Petty Trade	24	20%
	Domestic Work	12	10%
Ownership of TV	Yes	84	70%
	No	36	30%
Mobile Phone Ownership	Yes	108	90%
	No	12	10%
Participation in Government Welfare	Yes	66	55%
	No	54	45%
Any Outstanding Debt/Loan	Yes	48	40%
	No	72	60%

Table 3: Involvement in E-Waste Recycling

Variable	Response Option	Frequency (n)	Percentage (%)
How did you enter the activity?	Family business	48	40%
	Friend	36	30%
	Self-initiated	24	20%

	Agent	12	10%
Do you work daily?	Yes	96	80%
	No	24	20%
Average hours per day	<4	24	20%
	4–6	48	40%
	6–8	36	30%
	>8	12	10%
Do you handle hazardous materials?	Yes	72	60%
	No	48	40%
Do you use safety gear?	Always	48	40%
	Sometimes	36	30%
	Never	36	30%

Table 4: Knowledge, Attitudes & Perceptions

Statement	Frequency (n)	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Percentage (%)
I am proud of my work.	120%	6	12	18	36	48	100%
I believe this job poses a risk to my health.	120%	6	6	12	36	60	100%
Society looks down on e-waste workers.	120%	12	18	30	30	30	100%
I know what materials are harmful.	120%	12	18	48	24	18	100%
Children should not be involved in this work.	120%	6	6	12	36	60	100%

Table 5: Bivariate Analysis Results

Analysis Type	Variable Pair	Test Used	Test Statistic	p-value	Interpretation
Categorical vs. Categorical	Gender vs. Primary Source of Income	Chi-square test	$\chi2=4.8$	0.19	No significant association
Continuous vs. Continuous	Monthly Household Income vs. Average Hours Worked	Pearson's Correlation	$r = 0.45$	0.02	Moderate positive correlation, significant
Categorical vs. Continuous	Monthly Household Income vs. Number of Dependents	One-way ANOVA	$F = 6.5$	0.003	Significant difference in means
Categorical vs. Categorical	Gender vs. Monthly Household Income	Chi-square test	$\chi2=2.5$	0.47	No significant association
Categorical vs. Continuous	Access to Electricity vs. Number of Dependents	T-test	t-value	0.003	Significant difference in means
Categorical vs. Continuous	Access to Toilet vs. Number of Dependents	T-test	t-value	0.001	Significant difference in means
Categorical vs. Categorical	Voter ID Possession vs. Primary Source of Income	Chi-square test	$\chi2=3.6$	0.06	No significant association

Continuous vs. Continuous	Age vs. Number of Dependents	Pearson's Correlation	r = 0.23	-	Weak positive correlation

Table 6: Results for PCA

Variable	Component 1	Component 2	Component 3	Component 4
Age	0.68	0.28	-0.42	-0.32
Monthly Household Income	0.72	0.50	-0.18	0.15
Number of Dependents	-0.30	0.78	0.45	0.42
Education Level	0.35	-0.22	0.81	-0.26
Access to Electricity	0.55	-0.30	0.12	0.78
Access to Toilet	0.40	0.61	0.28	-0.50

Table 6: Factor Analysis Results

Variable	Factor 1 (Socioeconomic)	Factor 2 (Infrastructure)
Age	0.55	0.40
Monthly Household Income	0.70	0.20
Number of Dependents	0.60	0.35
Education Level	0.55	0.30
Access to Electricity	0.65	0.45
Access to Toilet	0.35	0.70

Table 7: Summary of Multivariate Logistic Regression

Variable	Coefficient (β)	Standard Error	Z-Value	p-value	Interpretation
Intercept	-1.20	0.35	-3.43	0.001	Baseline, when all predictors are zero.
Age	0.02	0.01	2.00	0.045	A one-year increase in age increases the odds of access by 1.02.
Income: ₹5,000–₹10,000	0.70	0.28	2.50	0.012	Increased odds of access to a toilet by 2.01 compared to <₹5,000.
₹10,001–₹20,000	1.00	0.35	2.86	0.004	Increased odds of access to a toilet by 2.72.
Income: >₹20,000	1.50	0.50	3.00	0.003	Increased odds of access to a toilet by 4.48.
Number of Dependents	-0.15	0.10	-1.50	0.135	No significant effect on access to the toilet.
Education: Secondary	0.50	0.30	1.67	0.095	A significant, though marginal, effect on toilet access.
Education: Higher Secondary	0.80	0.40	2.00	0.046	Increased odds of access to a toilet by 2.22.
Education: Graduate	1.20	0.45	2.67	0.008	Increased odds of access to a toilet by 3.32.
Access to Electricity	1.00	0.30	3.33	0.001	Increased odds of access to a toilet by 2.72.

Table 8: Results for Interaction Effect

Variable	Coefficient (β)	Standard Error	Z-Value	p-value
Intercept	-1.20	0.35	-3.43	0.001
Age	0.02	0.01	2.00	0.045
Income:	0.70	0.28	2.50	0.012
₹5,000–₹10,000				
₹10,001–₹20,000	1.00	0.35	2.86	0.004
>₹20,000	1.50	0.50	3.00	0.003
Number of Dependents	-0.15	0.10	-1.50	0.135
Education: Secondary	0.50	0.30	1.67	0.095
Education: Higher Secondary	0.80	0.40	2.00	0.046
Education: Graduate	1.20	0.45	2.67	0.008
Access to Electricity	1.00	0.30	3.33	0.001
Income × Access to Electricity	0.30	0.18	1.67	0.095

D. Discussion of Research Findings

i. Demographic Composition and Labour Vulnerability

Demography of respondents shows that 60% of the people involved in informal recycling of e-waste are women. This aligns with the research of Ongondo et al. (2022), who observed that women tend to occupy low-skilled sectors of the informal waste market due to their limited access to formal labour markets. This type of feminization of hazardous workplaces only increases the risk of occupational and reproductive health risk to the female struggling with the inconsistent use of personal protective equipment (PPE) that does not even occur between women in this study, only 40% affirmed adhering to protective measures even when 60% would handle hazardous substances. In addition, most respondents were married (50%). They resided in semi-permanent housing or temporary dwellings (70%), which is a trend that often leads to female involvement in low-income, high-risk lifestyles. Structural exclusion and dependence on informal sectors as a livelihood converge to become a source of gendered vulnerability, as captured by Chakraborty et al. (2021) and Chakraborty et al (2029), whose studies on electronic waste workers in Delhi, Kolkata, and other regions of India serve as a case in point.

ii. Educational Attainment and Occupational Trajectory

Although 70% of the respondents were well-educated, with at least a secondary education, and all of them were literate, this did not seem to translate into occupationalism and income mobility. It is contrary to the hypothesis of a normative development, which states that education increases socioeconomic status. Instead, according to the arguments independently presented by Isangadighi et al. (2025), Dasgupta (2000), Mbeng (2013) and Gutberlet (20212), when it comes to informal recycling businesses and other enterprises, educational attainment, without the specific interventions of industrial policy, cannot lift individuals out of poverty. The Bhavnagar results are also similar to those of other studies, which have claimed that education in informal Indian economies is more a means of survival than a means of upward mobility (Dutta & Goel, 2021; Vaid, 2016; and Froerer, 2011). Notably, the findings of the logistic regressions showed that increasing degrees of education (especially that of graduates) were tied with greater chances of gaining access to sanitation structures. The likelihood of accessing toilets was 3.32 times higher for graduates than for those who were not educated or at the primary level ($p = 0.008$). This was in tandem with Sthiannopkao and Wong (2013) as well as Siddiqui & Shokeen (2024), who noted that through education, people become empowered, gain access to basic social services, and utilize them effectively. However, in the case of economic vulnerability among the educated, the underlying problem is one of a systemic barrier to labour market absorption.

iii. Household Income, Work Intensity, and Poverty Dynamics

The income distribution revealed severe economic distress among e-waste laborers in Bhavnagar, where 80% of workers received a salary of less than 10,000 rupees per month, and 40% of them relied on e-waste recycling as their primary source of income. This income segment is indicative of the long-term poverty associated with the informal work situation. This finding aligns with a previous study conducted by Adama (2021), which also found the same level of income among informal recyclers in Nigeria. A significant but moderate correlation was found between work hours and income ($r = 0.45$, $p = 0.02$), indicating that income growth is not due to skill differentiation or productivity improvements, but rather to an increase in the number of working hours. This process of labour intensification exacerbates workplace fatigue and risk exposure, as reflected in the findings of Chowdhury et al. (2023, Islam & Alam (2019), Sultana et al. (2022) and Dartanto et al (2022), in their study of South Asian informal sectors, where a disparity often exists between hard labour and income or health expenses. The logistic regression also strengthened the notion that income is a critical determinant of

access to sanitation. Individuals with an income above ₹200,000 were 4.48 times more likely to either own or have access to a toilet ($p = 0.003$), which supports the idea that income graduation mediates access to assets in the field of public health. This has been correlated with empirical findings on inequality in access to sanitation at electronic waste sites by Adzawla et al. (2020), Blade et al. (2024), Dartanto et al (2022), and Huong et al. (2020), whose research documented that such inequality is driven by income in Ghana and Vietnam.

iv. Household Size and Infrastructure Access

The analysis also examined the impact of household size, serving as a proxy for the number of dependents, on socioeconomic outcomes. ANOVA indicated a strong correlation between household size and income ($F = 6.5$, $p = 0.003$), but in the logistic regression describing the likelihood of access to sanitation, the relationship was not significant ($p = 0.135$). This implies that although a large household size could lower per capita income, it does not statistically determine differences in access to infrastructure when other factors are held constant. This conclusion differs slightly from that of Isunju et al. (2011) and Isangadighi & Ukudo (2025), as the authors believe that the size of a household is a direct factor that leads to sanitation stress, particularly in urban slums. The differences can also be explained by contextual variables in Bhavnagar, including community toilets ownership or shared informal accommodation situations, which spread the effects of household size on access for individuals. Additionally, although 90% of the respondents had access to electricity, a minority had access to very reliable sanitation. The interaction between income and electricity access was just shy of significance (0.30, $p = 0.95$), indicating a possible synergy. This finding aligns with theories of multidimensional poverty (UN-Habitat, 2023); however, it is not a statistically significant relationship, as the individuals involved are not residing in the exact location during this study. Nonetheless, compounding assets such as income and infrastructure can create significant benefits in terms of well-being (Thams, 2022).

v. Multivariate Dimension Reduction and Structural Inference

It was decided to extract the latent variables causing the observed patterns by employing Principal Component Analysis (PCA) and Factor Analysis. As shown in PCA, the first component, which explained the most significant number of variances (35%), reflected the factors of age, income, and education; that is to say, the most significant structural influence on outcomes in informal recycling is socioeconomic status. Factor analysis revealed that two constructs, Socioeconomic Vulnerability and Infrastructure Access, exhibited significant differences, yet they still represented the interlocking deprivations that informal workers experience. The identified findings align with the multidimensional poverty frameworks used in South Asian countries by the Asian Development Bank (ADB, 2022 and Citaristi, 2011), which define poverty as sourced in the relationship not only to income but also access, awareness, and agency. The observed factor structure of Bhavnagar resembles that of urban slum dwellers in Mumbai (Singh & Kamble, 2022; Islam et al., 2025 and Isangadighi et al., 2025), making the latent constructs of the present research more generalizable.

vi. Perceptions, Risk Awareness, and Dignity in Informality

Knowledge, attitudes, and perceptions were also considered key psychosocial aspects of work. Although only 60% of the respondents reported that their occupation posed health threats to them, 48% of them went on to say that they were proud of their job. Such a paradox, previously mentioned by Blade et al. (2024) and Isangadighi & Udeh, 2023, presents an inquiry into a typical conflict in non-regulated economies, where dignity is an element that requires negotiation on fragile grounds. The correspondingly high support (60%) for the idea that children should not be involved in the work is another indication of a subtle community understanding of danger, despite the inaction of institutions. They were also asked about their feelings regarding a sense of social exclusion, to which they responded with strong support, with 60% agreeing that society looks down upon e-waste workers. This observation can be related to the stigma faced by waste pickers in Brazil (Dias & Samson, 2016), indicating that labour revalorisation in the context of environmental sustainability should be viewed through a socio-cultural lens.

In general, multivariate analysis offers a deeper insight into the relationship between socioeconomic characteristics as preconditions for accessibility to safe infrastructure, exposure to risks, stabilization, and occupational vulnerability. Education and income turned out to be the strongest predictors of infrastructural well-being, whereas household size and gender were less conclusive in a multivariate context. The results confirm that informal e-waste recycling is not a lifestyle feature; however, the expression of structural exclusions, the characteristic of poverty as a monetary measure, and the lack of infrastructure and policy at the particular level are factors. The article is therefore effective in supporting the need for specific measures to address the problem areas, including the inclusion of informal workers in urban waste management, strengthening protective laws, and access to health and sanitation services at a subsidized cost.

Originality Declaration

This paper has not been previously published in any Journal or is being considered for publication anywhere else.

Conflict of interest

The author states that no conflict of interest exists as far as the publishing of this article is concerned.

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Data Availability

The data generated in the course and/or analysed in this study shall be made available upon request to the corresponding author.

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