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Informing Efficient and Effective Solid Waste Management to Improve Local Environmental Quality and Public Health: Application of the Choice Experiment Method in West Bengal, India

by

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Informing Efficient and Effective Solid Waste Management to Improve Local Environmental Quality and Public Health: Application of the Choice Experiment Method in West Bengal, India

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Abstract

In this paper we employ the choice experiment method to estimate residents' willingness to pay (WTP) for improvements in the solid waste management (SWM) services provided in Chandernagore and South Dum Dum municipalities of Greater Kolkata in West Bengal, India. 101 randomly selected residents took part in a choice experiment survey. Data are analysed with conditional logit, random parameter logit and random parameter logit with interactions models. The best fitting random parameter logit with interactions model reveal that there is significant conditional and unconditional heterogeneity in residents' preferences for improvements in SWM services. The results reveal that on average residents of these municipalities are WTP significant amounts, in terms of higher monthly municipality taxes, to increase the frequency of waste collection, and to ensure that the waste is collected by covered trucks. Differences in WTP values across residents, however, should be taken into consideration to ensure social equity. The results reported in this paper have important policy implications for informing efficient, effective and equitable SWM services aimed at reducing local environmental pollution and the consequent public health risks.

Keywords: Municipal solid waste management, choice experiment, conditional logit model, random parameter logit model, interactions, preference heterogeneity, India.

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1. Introduction

Increasing levels of municipal solid waste (MSW) has long posed serious threats to local environmental quality and human health (NEERI 1994; Beede et al., 1995; CPCB, 2000; UN 2000). Especially during the last decade the volume and complexity of solid waste generated, particularly in large cities, have been increasing at an unprecedented rate. This increase has been attributed to two main drivers: intensification of urbanization and rising living standards (Rathi et al., 2007). The solid waste management (SWM) system comprises four activities: waste generation, collection, transportation, and disposal (Sharholy et al., 2007a). SWM therefore, requires adequate infrastructure provision and maintenance for all four activities. When not managed adequately, solid waste generates several public health and environmental hazards, a list of which is given in Table 1.

Table 1: Types of environmental and health hazards

Environmental and health hazards	Examples and causes
Environmental pollution	Air quality, water quality, land use, noise
Communicable diseases	Diarrhoea, Gastro-intestinal diseases, respiratory infection, skin diseases, jaundice,
Non-communicable diseases	Poisoning, hearing defects/loss, dust
Injury	Occupational injury by sharps, needles, glasses, metals, wood, violence etc.
Aesthetics	Odour, visibility, dust etc.

Source: Solid waste management manuals from Government of India (2000)

Increasing volume and complexity of solid waste pose the greatest challenges to large cities in developing countries, where the organization and planning of solid waste collection and disposal services tend to be rudimentary. Due to budget and infrastructure constraints, public authorities in these cities are often unable to manage large amounts of solid waste generated. This fact is reflected in the unknown volume and types of solid wastes collected; the amount recovered and recycled; the inadequacy of disposal sites, as well as inefficient reutilization and recycling programs (Buenrostro et al., 2003). Developing countries have similar patterns of SWM services which are characterised by lack of planning, poor or no segregation of waste at source, and unscientific and informal disposal systems. Lack of sufficient public and private funds and corrupt public sector are considered among the major bottlenecks to the improvement of the SWM services (Adedibu, 1985; Diallo and Coulibaly, 1991; Gupta et al., 1998; Buenrostro et al., 2001). Further, the negative externalities generated by increasing levels of unmanaged solid waste (as reported in Table 1) are exacerbated by the inadequate provision of other basic infrastructure and services such as water supply, sanitation facilities and transportation (UNCHS Habitat, 2001).

The situation of municipal solid waste (MSW) management in India is no less different. Currently, per capita MSW generated ranges from 0.2 to 0.5 kg per day per capita and is estimated to increase at a rate of 1 to1.33% annually (Pappu et al., 2007). The total MSW generated by 217 million people living in urban areas was calculated at 39 million ton in 2001, 63% higher than the 1991 figure of 23.86 million ton. The amount of MSW generated is expected to increase significantly in the near future as the country strives to attain an industrialized nation status by 2020 (Shekdar et al., 1992; CPCB, 2004; Sharma and Shah, 2005).

Similarly to other developing countries, suitable facilities to treat and dispose of MSW are lacking in metropolitan areas of India. MSW is often disposed of unscientifically and unsystematically, causing adverse impacts on the environment and public health (see for example Kansal et al., 1998; Kansal, 2002; Sharholy et al., 2005; Rathi., 2006; Sharholy et al., 2007). Lack of financial resources, institutional weaknesses and improper choice of technology and public apathy towards MSW are listed amongst the bottlenecks to provision of efficient and effective MSW management in India.

By the end of the 1990s, unacceptable levels of solid waste and consequent environmental and public health hazards led to the filing of a public interest litigation to the Honourable Supreme Court (HSC) of India. As a result the HSC commissioned a committee to investigate all aspects of SWM in the Class I[1] cities of India and to submit appropriate recommendations. On the basis of these recommendations (please see Committee Constituted by the HSC of India, 1999), a national legislation on the "Municipal Solid Waste (Management and Handling) Rules 2000" was adopted (Ministry of Environment and Forests, 2000). According to these rules, the municipal authorities have to develop a SWM system; provide appropriate sites for controlled disposal and treatment of waste. Based on this legislation, citizens may now file suit against municipal authorities for neglecting their waste management responsibilities, thus putting the municipalities under pressure to improve their services.

The aim of this study is to generate information to aid the designing of efficient and effective SWM services in two municipalities in Greater Kolkata, namely Chandernagore and South Dum Dum. To this end the stated preference choice experiment method is used to estimate residents' valuation of various SWM service attributes, including the frequency of waste collection, whether or not the vats are covered and whether or not the waste is collected by covered trucks. 101 residents are interviewed with a choice experiment and household survey instrument and their valuation of selected SWM service attributes is measured in terms of their willingness to pay (WTP) additional municipal taxes for improvements in the existing SWM services.

Several studies had employed stated preference methods (such as the contingent valuation and contingent ranking methods) to estimate the economic value of various SWM services, such as recycling and landfilling (see for example, Smith and Desvousges, 1986; Groothuis and Miller, 1994; Blore et al., 1996; Jakus et al., 1996; Lake et al., 1996; Tiller et al., 1997; Huhtala, 1999;

[1] Census of India classifies urban centres into six classes. Urban centres with populations of more than 100,000 are called a Class I cities. These cities are (in order of population) Greater Mumbai, Kolkata, Delhi, Chennai, Bangalore, Hyderabad, Ahemdabad, Pune, Surat, Kanpur, Jaipur, Lucknow, Nagpur, Patna, Indore, Vadodara, Bhopal, Coimbatore, Ludhiana, Kochchi, Vishakapatnam, Agra, Varanasi, Madurai, Meerut, Nashik, Jabalpur, Jamshedpur, Asansol, Dhanbad, Faridabad, Allahabad, Amritsar, Vijaywada and Rajkot.

Kinnaman, 2000; Caplan et al., 2002; Adland and Caplan, 2003; Bluffstone et al., 2003; Jenkins et al., 2003; Shinkuma., 2003). There is also an increasing number of choice experiment studies applied to value various attributes of SWM services (see for example, Garrod et al., 1998; Othman, 2002; Sasao., 2004; Jin et al., 2006; Sakata, 2006; Karousakis and Birol, 2007). This study is a valuable addition to the growing number of choice experiment studies applied to inform the provision of efficient and effective SWM services.

Moreover, to our knowledge, the choice experiment presented in this paper is the first such study applied to the topic of SWM services in India. A few other studies have tackled this issue using other methods. For example, Rathi (2007) applied a linear programming model to integrate different options and stakeholders involved in MSW management, whereas Chakrabarti (1998) developed a theoretical model for SWM. There have been several studies that investigated issues pertaining to composition, collection, recycling or landfilling (see for example, Yedla, 2003; Yedla et al., 2002; 2003; Rathi, 2006; Ghose et al., 2006; Sharholy et al., 2007b). The study presented in this paper is also a valuable addition to the economic studies implemented to inform SWM in India.

The next section describes the choice experiment method and the econometric models used. Section 3 explains the choice experiment design and survey administration, and presents the descriptive statistics. The results of the econometric analyses are reported in Section 4, and Section 5 concludes the paper.

2. The Choice experiment method

The choice experiment method has its theoretical grounding in Lancaster's model of consumer choice (Lancaster, 1966), and its econometric basis in random utility theory (RUT) (Luce, 1959; McFadden, 1974). Lancaster proposed that consumers derive satisfaction not from goods themselves but from the attributes they provide. To illustrate the basic model behind the choice experiment presented here, consider a respondent's choice of a SWM service. Assume that utility depends on choices made from a choice set C, which includes all possible SWM service alternatives. The respondent has a utility function of the form:

$$U_{ij} = V(Z_{ij}) + e(Z_{ij}) \,. \qquad (1)$$

For any respondent *i*, a given level of utility will be associated with any SWM service alternative *j*. Utility derived from any of the SWM service alternatives depends on the attributes of the SWM service (expressed in vector *Z*), such as the frequency of collection and whether or not the vats are covered.

RUT is the basis for integrating behaviour with economic valuation in the choice experiment method. According to RUT, the utility of a choice is comprised of a deterministic component (*V*) and an error component (*e*), which is independent of the deterministic part and follows a predetermined distribution. The error component implies that predictions cannot be made with certainty. Choices made between alternatives will be a function of the probability that the utility associated with a particular SWM service option *j* is higher than with other alternatives. Assuming that the relationship between utility and attributes is linear in the parameters and variables function, and that the error terms are identically and independently distributed with a Weibull distribution, the probability of any particular SWM service alternative *j* being chosen can be expressed in terms of a logistic distribution. Equation (1) can be estimated with a conditional logit model (CLM) (McFadden, 1974; Greene, 1997; Maddala, 1999).

The assumptions about the distribution of error terms that are implicit in the use of the CLM impose a particular condition known as the independence of irrelevant alternatives (IIA) property. IIA states that the relative probabilities of two options being chosen are unaffected by introduction or removal of other alternatives. If the IIA property is violated then CLM results will be biased. A second limitation of the CLM is that it assumes homogeneous preferences across respondents. As is well known in consumer theory, preferences are generally heterogeneous. Accounting for this heterogeneity enhances the accuracy and reliability of estimates of demand, participation, marginal and total welfare (Greene, 1997). Furthermore, accounting for heterogeneity enables prescription of policies that take equity concerns into account. An understanding of who will be affected by a policy change in addition to understanding the aggregate economic value associated with such changes is necessary (Boxall and Adamowicz, 2002).

Compared to the CLM, the random parameter logit model (RPLM) does not require the IIA assumption and can also account for unobserved, unconditional heterogeneity in preferences across respondents. The random utility function in the RPLM is given by:

$$U_{ij} = V(Z_j(\beta + \eta_i)) + e(Z_j) . \qquad (2)$$

Similarly to the CL model, utility is decomposed into a deterministic component (*V*) and an error component stochastic term (*e*). Indirect utility is assumed to be a function of the choice attributes (Z_j), with the utility parameter vector β, which due to preference heterogeneity may vary across respondents by a random component η_i. By specifying the distribution of the error terms *e* and η, the probability of choosing *j* in each of the choice sets can be derived (Train, 1998). By accounting for unobserved heterogeneity, the random parameter logit model (RPLM) takes the form:

$$P_{ij} = \frac{\exp(V(Z_j(\beta + \eta_i)))}{\sum_{h=1}^{C} \exp(V(Z_h(\beta + \eta_i)))} . \qquad (3)$$

Since this model is not restricted by the IIA assumption, the stochastic part of utility may be correlated among alternatives and across the sequence of choices via the common influence of η_i. Treating preference parameters as random variables requires estimation by simulated maximum likelihood. Procedurally, the maximum likelihood algorithm searches for a solution by simulating k draws from distributions with given means and standard deviations. Probabilities are calculated by integrating the joint simulated distribution.

Even if unobserved heterogeneity can be accounted for in the RPLM, however, this model fails to explain the *sources* of heterogeneity (Boxall and Adamowicz, 2002). One solution to detecting the sources of heterogeneity while accounting for unobserved heterogeneity could be to include interactions of respondent specific household characteristics with choice-specific attributes in the utility function. The RPLM with interactions can pick up preference variation in terms of both the unconditional heterogeneity of tastes (random heterogeneity) and individual characteristics (conditional heterogeneity), improving the fit of the model (Revelt and Train, 1998). When the interaction terms are included, the indirect utility function that is estimated becomes:

$$V_{ij} = \beta_1 Z_1 + \beta_2 Z_2 + ... + \beta_n Z_n + \delta_1 S_1 + \delta_2 S_2 + ... + \delta_l S_m . \qquad (4)$$

where *n* is the number of SWM service attributes considered and the vector of utility parameters β_1 to β_n are attached to the vector of attributes (*Z*). In this specification, *m* is the number of respondent-specific household characteristics that explain the choice of SWM service, and the vector of coefficients δ_1 to δ_l correspond to the vector of interaction terms (*S*) that influence utility. Since respondent-specific household characteristics are constant across choice occasions for any given respondent, they only enter as interaction terms with the SWM service attributes. Interaction terms help to capture heterogeneity across households, minimising the error component η_i.

3. Survey design and administration

3.1. Design of choice sets

The first step in CE design is to define the attributes of the SWM service. Following extensive review of the literature on SWM, and specific literature on SWM in India in general and in Chandernagore and South Dum Dum municipalities in particular; focus group discussions and informal interviews with residents of the two municipalities, and consultations with town planning experts, three important attributes and their levels were identified. A pilot contingent valuation study was conducted to identify the bid range of the monetary attribute required for estimating the value of the SWM service attributes. Overall a simple design was envisaged to reduce complex choice tasks and to avoid respondent fatigue. The attributes and the levels are reported in Table 2.

Table 2: SWM service attributes and attribute levels used in the choice experiment

Attributes	Definition	Levels
Frequency of vat collection	Number of times a day the waste is collected from the vat. At the vats are emptied once a day. Frequency of collection can be doubled to reduce excessive dumping and spillage.	*Once**,Twice
Covered vats	Whether or not the vats are covered. At the moment vats do not have covers. Uncovered vats cause littering of waste by stray dogs, bad odor, aesthetic unpleasantness and possible health risks. The vats can be covered by lids to prevent these problems.	*No*;Yes
Covered collection trucks	Whether or not the collection trucks are covered. At the moment waste collection trucks do not have covers. Uncovered trucks generate littering of the streets and bad odor, aesthetic unpleasantness and possible health risks. The collection trucks can be covered, to prevent these problems.	*No*;Yes
Additional municipality tax	Increase in monthly municipal tax each household would have to pay for improvement in the SWM services.	Rs 2, Rs 5, Rs 8, Rs 15

* Levels in italics indicate the status quo level.

Experimental design techniques (Louviere et al., 2000) and SPSS Conjoint software were used to obtain an orthogonal design, which consisted of only the main effects, and resulted in 32 pairwise comparisons of SWM services. These were randomly blocked to four different versions, each with eight choice sets. Each set contained two SWM services and an 'opt out' option, which is considered as a status quo or baseline alternative whose inclusion in the choice set is instrumental to achieving welfare measures that are consistent with demand theory (Louviere et al., 2000; Bateman et al., 2003). Figure 1 provides an example of a choice set.

Figure 1: Example of a choice set

Assuming that the following three waste management options were the only choices you had, which one would you prefer?

	Solid Waste Management Service A	Solid Waste Management Service B	Current Solid Waste Management Service: Status Quo
Frequency of vat collection	ONCE A DAY	TWICE A DAY	ONCE A DAY
Covered vats	YES	NO	NO
Covered collection trucks	NO	YES	NO
Monthly increase in tax (Rs)	8	5	0
I prefer	Option A	Option B	Status Quo Option

3.2. Data Collection and Sample

Of the 125 municipalities in West Bengal, two were chosen to represent the current status of SWM services provided and the environmental and health risks associated with inefficient and ineffective management of MSW. The first municipality, South Dum Dum has a population of about 392,150 (Census of India, 2001) and is spread over an area of 17.96 km^2, covering 35 wards. This municipality generates 201 metric tons of solid waste every day. Even though there is a solid waste collection service provided by the municipality, the frequency of collection is low compared to the amount of waste generated. Consequently, 40% of the household waste generated ends up being discarded in public areas and roadsides (Socio-economic Survey of South Dum Dum municipality, 2007). Moreover heavy metal contamination of lead and zinc at the dumping grounds cause serious health hazards. The second municipality is Chandernagore with population of 162,166 (Census of India, 2001). This municipality is spread over a total area of 20 km^2, covering 33 wards. 400 metric tons of solid waste is generated daily, most of which is disposed off near the bank of the river Ganges as well as at the open landfill site, thereby creating environmental pollution and public health hazard. Littering of waste due to open vats and uncovered trucks used for transportation are common phenomena in this municipality.

The CE and household survey was administered in April and May, 2007 with face-to-face interviews of 101 residents in the Chandernagore and South Dum Dum municipalities. The sampling frame consisted of two randomly selected wards in each municipality. A quota sample was collected and the survey was administered to be representative of the total population of the municipality in terms of income, social status and proximity to the vat. An introductory section explained to the respondents the context in which choices were to be made and described each attribute, and their present status. Respondents were reminded that there were no right or wrong answers and that we were only interested in their opinions. They were also told that the municipalities did not have sufficient funds to improve the SWM services, and therefore it would be necessary to increase the monthly municipal taxes paid by the households. The respondents were also reminded of their budget constraints.

In addition to the eight choice experiment questions, data were also collected on social and economic characteristics of the respondents and the current SWM services they receive from their municipalities. The descriptive statistics are reported in Table 3.

Table 3: Social and economic characteristics of the households

Household social and economic characteristics	Mean (Std.Dev.)
Years household has been a resident of the municipality	21.52 (16.69)
Distance of the household's residence from the nearest vat (in minutes)	7.59 (4.1)
Household size	5.44(3.89)
Monthly expenditure of the household (proxy income) (Rs)	9061.63(6044.46)
Number of children	1.45 (0.7)
Age of the head of the household	51.85(17.03)
Age of the waste manager	36.36(13.15)
	Percent
Household has children (yes=1, 0 otherwise)	59.4
Gender of household head (female=1,male=0)	8
Education level of household head	
University graduate =1,0 otherwise	28.7
Post-graduate=1, 0, otherwise	18.8
Occupation of the household head	
Civil service	25.7
Self-employed	47.5
Pensioner	20.1
Gender of the waste manager(female=1,0 otherwise)	93.1
Education level of the waste manager	
Less than mandatory level	44.6
Higher secondary	19.8
University graduate	15.8
Occupation of the waste manager	
Housewife	56.4
Domestic help	27.7

Source: West Bengal Solid Waste Management Choice Experiment and Household Survey, 2007

On average respondents have been residents in the area for about 21.5 years. Their average distance to the nearest vat is 7.6 minutes. The household size is 5.4 people, almost 60% of the household have children younger than 18 years of age residing at home, and the average number of children is 1.5. 92% of the households are headed by male members, and the average age of the household heads is 51.9. Majority of the household heads are university graduates (28.7%), followed by postgraduates (18.8%). 47.5% of the household heads are self-employed, followed by civil servants (25.7%) and pensioners (20.1%). The main waste managers are women (93.1%) and their average age is 36.4. Almost half of the waste managers (44.6%) have less than minimum level of education, followed by higher secondary school (19.8%) and university graduates (15.8%). Over half of the household waste managers (56.4%) are housewives, followed by domestic helper. Average monthly household expenditure, as a proxy for income is Rs 9061.634 (approximately €157.67). This figure is comparable to the monthly GDP per capita in India, which was estimated to be €144 in 2007 (World Fact Book, 2008). Over half of the monthly household expenditure (Rs 4617.8) is spent on food, followed by transport and health.

Respondents' opinions of the current SWM services provided by the municipalities and the main problems associated with lack of adequate SWM were also elicited through a series of questions posed on a Likert Scale. Summary statistics of respondents' answers to these questions are presented in Table 4.

Overall, 36.7% of the respondents agree or strongly agree with the statement that they are satisfied with the existing system of collection from the vat. 32.8% of the respondents agree or strongly agree that they find the size and conditions of the vat provided in the locality satisfactory. Therefore, almost two thirds of the residents are not content with the current collection and vat services provided by the municipalities. Almost two thirds (57.6%) of the respondents agree or strongly agree that other residents of the municipality must be more environmentally aware and stop littering and throwing garbage openly in the street. Regarding the most important problem related to the SWM in the area, a great majority (71%) of the respondents strongly agree or agree that the vats generate unpleasant odours, this is followed by odour generated by litter (66.7%), public health risks generated by inadequate SWM services (63.5%), nuisance from the flies due to litter and open vats (62%), and contamination of groundwater(13.1%).

Table 4. Residents' opinions of the current SWM services and problems

Statement	Strongly Disagree	Disagree	Neither agree nor disagree	Agree	Strongly Agree
Opinions on the current SWM services provided by the municipality					
I am satisfied with the existing system of collection from the vat	0	34.7	28.6	35.7	1
I am satisfied with the size and conditions of the vat provided in the locality	4.9	31.2	31.2	29.5	3.3
Other residents of the municipality must be more environmentally aware and stop littering and throwing garbage openly in the street	5.4	18.5	18.5	21.7	35.9
Opinions on the most important problem(s) related to the SWM in this municipality					
Public health risk	0	10.4	26	42.7	20.8
Groundwater contamination from the dumping site	2.4	39.3	45.2	9.5	3.6
Aesthetic disturbance generated by litter	3.1	22.7	35.1	34	5.2
Unpleasant odor generated by litter	3	18.2	12.1	44.4	22.2
Nuisance from flies	1	18	19	33	29
Unpleasant odor generated by vats	1	17	11	39	32
Long distance between the residency and the nearest vat	4.3	77.7	17	0	1.1

Source: West Bengal Solid Waste Management Choice Experiment and Household Survey, 2007

4. Results

4.1 Conditional logit model

The choice experiment was designed with the assumption that the observable utility function would follow a strictly additive form. The model was specified so that the probability of choosing a particular SWM service was a function of the four attributes. Using the 808 choices elicited from the 101 respondents, the conditional logit model (CLM) was estimated using LIMDEP 8.0 NLOGIT 3.0. The results are reported in Table 5.

Table 5. Conditional logit model for SWM service attributes

Attributes	Coeff. (Std.Err)
Frequency of vat collection	0.352*** (0.045)
Covered vats	0.178***(0.047)
Covered collection trucks	0.117** (0.049)
Monthly increase in	-0.073*** (0.011)
ρ^2	0.045
Log-likelihood	-847.704
Sample size	808

Source: West Bengal Solid Waste Management Choice Experiment and Household Survey, 2007

*** 1% significance; **5% significance and *10% significance level with two-tailed tests.

The overall fit of the model, as measured by McFadden's ρ^2 is low, though all the coefficients are statistically significant and intuitively correct. All the SWM service attributes are significant factors in the choice of a SWM service and *ceteris paribus*, higher levels of the three attributes increases the probability that a SWM service is being selected. In other words, households prefer those SWM services which collect waste from vats twice a day, provide covered vats and collect waste with covered trucks. The coefficient on the frequency of vat collection is the highest, revealing that this is the most important determinant of SWM service choice, followed by covered vats and covered collection trucks. Finally, the sign of the payment attribute is negative and significant, as expected

To test whether the CLM is the appropriate model specification, Hausman and McFadden (1984) test is carried out. The IIA property is significantly violated when any of the three choice alternatives are dropped from the choice sets, indicating that the model does not fully conform to the underlying IIA property. Therefore the model needs to be augmented either by employing the random parameter logit model (also referred to as mixed logit) or by including social and economic characteristics as interaction terms, or both (Revelt and Train 1998).

4.2. Random Parameter Logit Model

The random parameter logit model (RPLM) (Train, 1998) is estimated using LIMDEP 8.0 NLOGIT 3.0. The results of the RPLM estimations are reported in the Table 6.

Table 6: Random Parameter Logit Model (RPLM) and RPLM with Interactions

Attributes and Interactions	RPL Model		RPL with Interactions	
	Coeff. (s.e.)	Coeff. Std. (s.e.)	Coeff. (s.e.)	Coeff. Std. (s.e.)
Frequency of vat collection	0.883*** (0.246)	0.587 (0.557)	0.586*** (0.076)	0.026 (0.272)
Covered vats	-0.172 (0.304)	3.559** (1.796)	0.012 (0.118)	1.747*** (0.328)
Covered collection trucks	0.320** (0.145)	0.015 (0.188)	0.270*** (0.073)	0.008 (0.194)
Monthly increase in municipality tax	-0.190*** (0.055)	-	-0.358*** (0.040)	
Tax x total expenditure	-	-	0.00002*** (0.230)	-
Tax x education of the household head	-	-	0.124*** (0.030)	-
Tax x satisfaction with current SWM services	-	-	-0.268*** (0.071)	
Tax x domestic help manages waste	-	-	0.183*** (0.041)	
ρ^2	0.0730		0.174	
Log likelihood	-822.921		-733.579	
Sample size	808		808	

Source: West Bengal Solid Waste Management Choice Experiment and Household Survey, 2007
*** 1% significance; **5% significance and *10% significance level with two-tailed tests.

The RPLM compared to the CLM has a higher level of parametric fit, as ρ^2 increases, and log-likelihood decreases. These improvements can be tested for significance with a version of a Swait Louviere log likelihood ratio test. The calculated statistics is -2[-847.7-(-822.9)]=48.2 which is larger than 11.05 the critical value of $\chi 2$ distribution at 3 degrees of freedom at 2.5% significance level, where the degrees of freedom are given by the difference in the numbers of parameters estimated in the two models. This result indicates that the improvement in model fit is significant. Therefore the RPLM is a better fit for the estimation of the data.

The model results reveal that the covered vat attribute supports a significant and large standard deviation, and almost half (48.1%) of the households prefer vats without lid. The high level of heterogeneity in residents' preference for this attribute, as evident in the significant and large attribute standard deviation, results in the insignificance of the overall coefficient mean. When the heterogeneity of this attribute is taking into account with the use of the RPLM the model fit increases considerably. The other two attributes have insignificant standard deviations; all households prefer covered collection trucks, and almost all (94%) prefer waste to be collected from the vats twice a day.

4.3. Random Parameter Logit model with interactions

Even if unobserved heterogeneity can be accounted for in the RPLM, the model fails to explain the *sources* of heterogeneity (Boxall and Adamowicz, 2002). In order to identify the possible sources of heterogeneity, interactions of respondent-specific social and economic characteristics and opinions with choice specific attributes were included in the utility function. After extensive testing of the various interactions of the three attributes with the social and economic characteristics and opinions reported in Tables 3 and 4, the RPLM where the tax attribute was interacted with the households' total monthly expenditure (proxy of income); whether or not the household head has a university degree or above; whether or not the household is satisfied with the existing vat collection services, and whether or not the domestic help manages the household waste was found to fit the data best. Correlation among these variables is found to be insignificant. The indirect utility function is extended to include these interactions and the RPLM with interactions was estimated using LIMDEP 8.0 NLOGIT 3.0. The results are reported in the last columns of Table 6.

The RPLM with interactions compared to the RPLM has a higher level of parametric fit, as ρ^2 increases, and log-likelihood decreases. Swait Louviere log likelihood ratio test is -2[-822.9-(-733.6)] =178.6, which is larger than 14.86 the critical value of $\chi 2$ distribution at 4 degrees of freedom at 0.5% significance level. Therefore the RPLM with interactions is the best fit for the data. Similarly to the results of the RPLM, the results of RPLM with interactions reveal that the standard deviations for frequency of vat collection and covered collection trucks are insignificant; all households prefer higher levels of these attributes. The standard deviation for the covered vat attribute supports a significant and large indicating that 49.7% of all households prefer vats without lid. This variation around the mean results in the coefficient of this attribute to be insignificant.

The interactions between monthly increase in municipal tax and expenditure; whether or nor the household head has university degree or above, and whether or not the domestic help managed the household waste are significant and positive. These results reveal that households with higher levels of income, those headed by university graduates and those households whose domestic help manage the waste prefer to pay more for improvement of SWM services. On the other hand, as expected, households that are content with the current SWM services prefer to pay less taxes for improvement of these services. The sign and significance level of the estimated parameters on the respondent characteristics provide construct validity for the choice experiment results.

4.4. Estimation of Willingness to pay:

The choice experiment method is consistent with utility maximisation and demand theory (Bateman et al. 2003). Welfare measures can be calculated from the parameter estimates by using the following formula:

$$CS = \frac{\ln \sum_i \exp(V_{i1}) - \ln \sum_i \exp(V_{i0})}{\alpha} \qquad (5)$$

where CS is the compensating surplus welfare measure, α is the marginal utility of income (represented by the coefficient of the monetary attribute in the choice experiment, which is municipal tax in this case) and V_{i0} and V_{i1} represent indirect utility functions before and after the change under consideration.

For the linear utility index the marginal value of change in a single SWM service attribute can be estimated as a ratio of coefficients. The ratio represents the marginal rate of substitution between money and the SWM service attribute in question, or the marginal welfare measure (willingness to pay (WTP)) for a change in any of the attributes. For the binary SWM service attributes which are effects coded, equation (5) reduces to a part-worth (or marginal implicit price) formula (see, Hu et al., 2004):

$$WTP = -2\left(\frac{\beta_{attribute}}{\beta_{monetary\,variable}}\right) \qquad (6)$$

The demand functions conditional on the respondent characteristics reported in Table 6 can be used to calculate the value assigned by the respondent to SWM service attributes, by modifying Equation (6):

$$W = -2\left(\frac{\hat{\beta}_{attribute} + \delta_{atribute} \times S_1 ... + \delta_{attribute} \times S_4}{\hat{\beta}_{monetaryattribute} + \delta_{monetaryatribute} \times S_1 + ... + \delta_{monetaryattribute} \times S_4} \right) \quad (7)$$

where variables S_{1-4} are the four respondent-specific characteristics under consideration. Using the Wald Procedure (Delta method) in LIMDEP 8.0 NLOGIT 3.0, respondents' WTP for SWM service attributes was calculated for the average household for the three models (CLM, RPLM and RPLM with interactions) for comparison purposes. Table 7 reports the marginal WTP results for CLM and RPLM.

Table 7: Marginal WTP for SWM service attributes(95% C.I) in Rs/household/month

Attributes	CLM	RPLM
Frequency of vat collection	-9.61***(-11.09- -8.13)	-9.32***(-10.19- -8.45)
Covered vats	-4.85***(-6.00- -3.70)	-1.81(-1.12- -4.74)
Covered collection trucks	-3.19***(-4.40- -1.98)	-3.38***(-4.16- -2.6)

Source: West Bengal Solid Waste Management Choice Experiment and Household Survey,2007
*** 1% significance; **5% significance and *10% significance level with two-tailed tests.

According to WTP estimated driven from the CLM, households are WTP as high as Rs 9.6 more per months to ensure the vats are collected twice daily. They are WTP further Rs 4.9 for covered vats and Rs 3.2 for covered collection trucks to be provided by the municipality SWM services. RPLM estimates are similar, though the average WTP for covered vats are insignificant.

In order to estimate heterogeneity of WTP across households, six household profiles were generated. The first two profiles were generated according to total household expenditure, i.e., income level. The first profile belongs to poorer households whose expenditure is less than or equal to 25% percentile, and the second profile belongs to the average of wealthier households whose expenditure is more than or equal to 75% percentile. The next two profiles are based on whether or not the households are satisfied with the current SWM services, and the final two household profiles are generated conditional on the education level of the household head. The average statistics for these profiles are reported in Table 8.

Table 8. Average social and economic characteristics of the six household profiles

	Total household Monthly	Household head Has university Degree	Satisfied with SWM Services	Domestic help SW Manager
Profile 1	3608	32%	12%	4%
Profile 2	16729	56%	8%	44%
Profile 3	9207	56%	0%	31%
Profile 4	7872	36.4%	100%	0%
Profile 5	9234.4	100%	7.4%	46.3%
Profile 6	8863	0%	14.9%	6.4%

Source: West Bengal Solid Waste Management Choice Experiment and Household Survey, 2007

The marginal WTP values for these profiles and for the average household profile for the RPLM with interactions are reported in Table 9. The results reveal that in this model WTP values for profiles 2 and 5 are insignificant. The WTP values for the covered vats attribute for all household profiles are also insignificant, due to the extreme heterogeneity (bi-polarity of preference intesnities for this attribute. Profile 3 is WTP the most to ensure vats are emptied twice a day and they are collected by covered trucks, whereas Profile 4 is WTP the least for these attributes. These results are in line with those of Othman (2002), who found that respondents exhibit significant WTP values for higher collection frequencies, as well as for improvements in the mode of transportation of waste, from a mix of compactor and open trucks to either compactor or a mix of compactor and covered trucks.

Table 9: Marginal WTP for SWM service attributes (95% C.I) in Rs/household/month for RPLM with interactions

	Frequency of vat collection	Covered vats	Covered collection trucks
Average household	-9.46***(-10.89- -8.45)	-0.18(-2.07- -1.71)	-4.36***(-5.45- -3.27)
Profile 1	-4.11*** (4.60- -3.62)	-0.08(-.90- -.74)	-1.89***(-2.36- -1.42)
Profile 2	20.06 (7.52- 32.6)	0.39(-3.7-4.48)	9.25(2.98-15.52)
Profile 3	-28.79*(-45.06- -12.52)	-0.56(-6.22-5.1)	-13.27*(-20.86- -5.68)
Profile 4	-2.57***(-3.01- -2.13)	-0.05(-.57- .47)	-1.19***(-1.52- -85)
Profile 5	-57.18 (125.09-10.73)	-1.12(-12.24 -10)	-26.36(-57.62-4.9)
Profile 6	-4.79***(-5.38- -4.2)	-0.094(-1.05-.87)	-2.21***(-2.76- -1.66)

Source: West Bengal Solid Waste Management Choice Experiment and Household Survey, 2007
*** 1% significance; **5% significance and *10% significance level with two-tailed tests.

In order to assess whether there are significant differences between the WTP values of the average household profile and the four profiles which exhibited significant WTP values for frequency of vat collection and covered collection trucks attributes, a Poe et al. (1994) simple convolutions process was undertaken (Rolfe and Windle, 2005). After having calculated the WTP using the Wald Procedure (Delta method) in LIMDEP 8.0 NLOGIT 3.0, differences between WTP values were calculated by taking one vector of WTP from another. The 95% confidence interval is approximated by identifying the proportion of differences that fall below zero. The results reveal that the differences between the WTP for the average household and the first, fourth and sixth household are significantly different than zero at 1% significance level (Table 10). Therefore, there is significant heterogeneity for WTP for these attributes within the sampled population.

Table 10: Proportion of WTP differences for SWM service attributes falling below zero

	Frequency of Vat collection	Covered collection trucks
Average vs. Profile 1	1	0.99975
Average vs. Profile 3	0.89745	0.8989
Average vs. Profile 4	1	0.99995
Average vs. Profile 6	1	0.99965

5. Conclusions and Policy Implications

This paper contributes to the growing literature on the estimation of economic values generated by improved SWM services by using the choice experiment method. Moreover, it contributes to the limited number of choice experiment studies undertaken in developed countries, and presents one of the first choice experiment studies implemented in India. There are to date very few CE studies carried out in developing countries and following the conclusions of Othman et al. (2004), this study reveals that the choice experiment method can be successfully employed in a developing country with careful construction of simple choice sets and effective field data collection.

To this end, a choice experiment study is carried out with 101 residents of South Dum Dum and Chandernagore municipalities in Greater Kalkota, West Bengal. A random parameter logit model with interactions was estimated to estimate the benefits residents derive from improved SWM services, and the social and economic characteristics and opinions that affect residents' valuation of improved SWM services. The SWM service attributes of focus in this study are the frequency of collection of waste from the vats, covered vats and covered waste collection trucks. The results of this model indicate that the public on average does care about improvements in SWM in their locality. There are significant economic benefits associated with improving the SWM services, especially with increasing the collection of waste from the vats to twice daily, and ensuring that the waste collection trucks are covered. The impacts of social and economic characteristics, and opinions of respondents on their valuation of SWM service attributes are significant and conform with economic theory.

The results of this study reveal that even though there is significant heterogeneity within the population, and despite tight budget constraints, overall the residents sampled exhibit significant WTP to ensure improvements in SWM services. Although the sample size is small, the income level (as measured by total household expenditure) of the sampled population is comparable to that of Indian average. SMW service inadequacies experienced by Chandernagore and South Dum Dum municipalities are representative of other municipalities in India. We can therefore argue that overall Indian population demands improved SWM services from their municipalities, and they are WTP for it.

SWM is a vital, ongoing and large public service system, which needs to be efficiently and effectively provided to minimise environmental and public health hazards generated by SWM. The results presented in this paper therefore have important implications for improvements in the current SWM services provided by municipalities, which are far from adequate. With the use of the benefits transfer method, the results of this case study can provide other municipality level policy-makers with useful information for efficient and effective improvements in their existing SWM services.

6. References

Aadland, D. and Caplan, A.J.(2003):Willingness to Pay for Curbside Recycling with Detection and Mitigation of Hypothetical Bias. American Journal of Agricultural and Resource Economics 85(2), pp 492-502.

Adedibu, A.A.(1985): A comparative analysis of solid waste composition and generation in two cities of a developing nation. The Environmentalist 1985; 5(2), pp123 -7.

Bateman, I.J., Carson, R.T., Day, B., Hanemann, W.M., Hanley, N.,Hett, T., Jones-Lee, M., Loomes, G., Mourato, S., Ozdemiroglu, E., Pearce, D.W., Sugden, R., Swanson, S.(2003): Guidelines for the Use of Stated Preference Techniques for the Valuation of Preferences for Non-market Goods. Edward Elgar, Cheltenham.

Beede, D.N. and Bloom, D.E. (1995): The Economics of Municipal solid waste, The World Bank Research Observer 10(2), pp 113-50.

Blore, I. and Nunan, F.(1996): Living with waste: public valuation of solid waste impacts in Bangkok. Papers in the Administration of Development No. 57. University of Birmingham, Birmingham, UK: Development Administration Group.

Bluffstone, R. and Shazo, J.R. (2003):Upgrading municipal environmental services to European union levels: a case study of household willingness to pay in Lithuania, Environment and Development Economics 8, pp 637-654

.Boxall, P.C., and Adamowicz, W.L. (2002):Understanding heterogeneous preferences in random utility models: a latent class approach. Environmental and Resource Economics 23, pp 421–446.

Buenrostro, O., Bocco, G., and Bernache, G.(2001): Urban solid waste generation and disposal in Mexico. A case study. Waste Management and Research 19, pp169-76.

Buenrostro, O. and Bocco, G. (2003): Solid waste management in municipalities in Mexico: goals and perspectives Resources, Conservation and Recycling 39(3), pp 251-263.

Caplan, A., Grijalva, T.C., and Jakus, P.M. (2002): Waste Not or Want Not: A Contingent Ranking Analysis of Curbside Waste Disposal Options, Ecological Economics 43, pp 185-197.

Central Pollution Control Board (CPCB) (2004): Management of Municipal Solid Waste. Ministry of Environment and Forests, New Delhi, India.

Chakrabarti S.(1998): Policy Model for Management of Urban Waste, Journal of Policy Modeling 20(1), pp 45-54.

CPCB (Central Pollution Control Board) (2000): Management of MSW, Ministry of Environment and Forests, Government of India.

Diallo, S. and Coulibaly, Y. (1991): Urban waste in the slums of Bamako, In: ENDA, editor. Man and Waste. Popular Recycling Activities in the Third World, VIII, 1, 2. Dakar, 1991. pp 69-88.

Directorate of Census Operations, West Bengal (2001): Census of India, http://www.wbcensus.gov.in/

Garrod, G. and Willis, K.(1998): Estimating lost amenity due to landfill waste disposal, Resources Conservation and Recycling 22, pp 83-95

Ghose, M.K., Dikshit, A.K. and Sharma, S.K. (2006): A GIS based transportation model for solid waste disposal – A case study on asansol municipality. Journal of Waste Management 26 (11), pp 1287–1293.

Greene, W.H(1997):Econometric Analysis, fourth ed. Prentice-Hall

Groothuis, P. and Miller, G. (1994):Locating Hazardous Waste Facilities: The Influence of NIMBY Beliefs American Journal of Economics and Sociology, 53(3), pp 335-346.

Gupta, S., Krishna, M., Prasad, R.K., Gupta, S. and Kansal, A. (1998): Solid waste management in India: options and opportunities. Resource, Conservation and Recycling 24, pp 137–154.

Hausman J.A. and McFadden, D. (1984): Specification Tests for the Multinomial Logit Model, Econometrica 52, pp1219-1240.
Hu, W., Hunnemeyer, A., Veeman, M., Adamowicz, W.L. and Srivastava, L. (2004):Trading off health, environmental and genetic modification attributes in food. European Review of Agricultural Economics 31, pp 389-408.
Huhtala. A.(1999): How much do money, inconvenience and pollution matter? Analysing households' demand for large-scale recycling and incineration, Journal of Environmental Management 55, pp 27-38.
Jakus, P. M., Tiller, K.H., and Park, W.M. (1996): Generation of Recyclables by Rural Households, Journal of Agricultural and Resource Economics 21(1), pp 96-108.
Jenkins R.R., Martinez S.A., Palmer K., and Podolsky M.J.(2003): The determinants of household recycling: a material –specific analysis of recycling program features and unit pricing, Journal of Environmental Economics and Management 45(2), pp 294-318.
Jin J., Wang Z and Ran, S. (2006): Comparison of contingent valuation and choice experiment in solid waste management programs in Macao, Ecological Economics 57(3), pp 430-441
Kansal, A. (2002): Solid waste management strategies for India. Indian Journal of Environmental Protection 22 (4), pp 444–448.
Kansal, A., Prasad, R.K., and Gupta, S.(1998): Delhi municipal solid waste and environment – an appraisal. Indian Journal of Environmental Protection 18 (2), 123–128.
Karousakis, K. and Birol, E.(2007): Investigating household preferences for kerbside recycling services in London: A choice experiment approach, Journal of Environmental management, doi:10.1016/j.jenvman.2007.05.015
Kinnaman, T. (2000):The Efficiency of Curbside Recycling: A Benefit-Cost Analysis. Journal of Public Works Management and Policy, 5 (1), pp 37-51.
Lake, I., Bateman, I.J. and Parfitt, J.P.(1996): Assessing a Kerbside Recycling Scheme: A Quantitative and Willingness to Pay Case Study , Journal of Environmental Management 46(3), pp 239-254
Lancaster, K. (1966): A new approach to consumer theory, Journal of Political Economics 74, pp 217–231.
Louviere, J.J., Hensher, D. Swait, J., and Adamowicz, W. (2000): Stated Choice Methods: Analysis and Applications. Cambridge University Press, Cambridge.
Luce, D. (1959):Individual Choice Behaviour. Wiley, New York, NY.
Maddala, G.S. (1999):Limited Dependent and Qualitative Variables in Econometrics. Cambridge University Press, Cambridge.
McFadden, D. (1974):Conditional logit analysis of qualitative choice behavior. In: Zarembka, P. (Ed.), Frontiers in Econometrics. Academic Press, New York.
NEERI (National Environmental Engineering Research Institute)(1994): Solid Waste Management in Greater Bombay: Final Report.
Othman, J.(2002):'Household preferences for Solid Waste Management in Malaysia', http//www.eepsea.org .
Pappu, A., Saxena, M. and Asokar, S.R.(2007):Solid Waste Generation in India and Their Recycling Potential in Building Materials, Journal of Building and Environment 42 (6), pp 2311–2324.
Poe, G.L., Severance-Lossin, E.K. and Welsh, M.P.(1994): Measuring the difference (X–Y) of simulated distributions: a convolutions approach, American Journal of Agricultural Economics 76, pp 904–915.
Quick Brain (2007) :Socio Economic Survey Report for DDP-SDDM, 2007.
Rathi, S.(2007): Optimization model for integrated municipal solid waste management in Mumbai, India, Environment and Development Economics 12, pp 105-21
Rathi, S., (2006):Alternative approaches for better municipal solid waste management in Mumbai, India, Journal of Waste Management 26(10), pp 1192–1200.

Revelt, D., Train, K(1998):Mixed logit with repeated choices: households' choice of appliance efficiency level. Review of Economics and Statistics 53, pp 647–657.

Rolfe J.R. and Windle, J.(2005): Valuing options for reserve water in the Fitzroy Basin, The Australian Journal of Agricultural and Resource Economics 49(1), pp 91-114.

Sakata Y.(2007): A choice experiment of the residential preference of waste management services – The example of Kagoshima city, Japan, Waste Management 27(5), pp 639–644

Sasao, T.(2004): An estimation of the social costs of landfill siting using a choice experiment Waste Management Vol 24, pp 753–762

Sharholy, M., Ahmad, K., Mahmood, G., and Trivedi R.C. (2007a): Municipal solid waste management in Indian cities – A review, Waste Management 28(2), pp 459-467

Sharholy, M., Ahmad, K., Mahmood, G., and Trivedi, R.C.(2005):Analysis of municipal solid waste management systems in Delhi – a review. In Book of Proceedings for the second International Congress of Chemistry and Environment, Indore, India, pp. 773–777.

Sharholy, M., Ahmad, K., Vaishya, R.C., and Gupta, R.D.(2007b): Municipal Solid Waste Characteristics and Management in Allahabad, India, Waste Management 27 (4), pp 490–496.

Sharma, S., and Shah, K.W.(2005): Generation and disposal of solid waste in Hoshangabad:. In Book of Proceedings of the Second International Congress of Chemistry and Environment, Indore, India, pp. 749–751.

Shekdar, A.V., Krishnawamy, K.N., Tikekar, V.G., and Bhide, A.D.(1992):Indian urban solid waste management systems – jaded systems in need of resource augmentation, Journal of Waste Management 12 (4), pp 379–387.

Shinkuma, T.(2003): On the second-best policy of household's waste recycling, Environment and Resource Economics 24(1), pp 77-95

Smith, K. and Desvouges, W.(1986): Measuring Water Quality Benefits, in Economic Modelling, Kluwer-Nijhoff, Boston, pp145-80.

Solid waste management manuals from Government of India: http://www.hpurbandevelopment.nic.in/SWM%20manual.htm

Tiller, K.H., Jakus, P. M. Park, W.M.(1997):Household willingness to pay for drop-off recycling, Journal of Agricultural and Resource Economics 22(12), pp 310-20.

Train, K.E. (1998): Recreation demand models with taste differences over people, Land Economics 74, pp 230–239.

UN (2000): State of the Environment in Asia and the Pacific. United Nations Economic and Social Commission for Asia and Pacific and Asian Development Bank, United Nations Publication, New York.

UNCHS (Habitat), 2001. The State of the Worlds Cities 2001, Nairobi,Kenya.

Yedla, S. and Kansal, S.(2003): Economic insight into municipal solid waste management in Mumbai: a critical analysis, International Journal of Environment and Pollution 19(5), pp 516-27.

Yedla, S. and Parikh J.K.(2002): Development of a purpose built landfill system for the control of methane emissions from municipal solid waste, Waste management 22(5), pp 501-506.

Yedla, S.(2003): Development of techno-economic integrated models: LFSGR and aerobic composting for municipal waste management , 8 pp 655-677