Cost analysis of Municipal Solid Waste Management in India

1. Introduction

Solid waste management (SWM) is a critical problem for developing countries such as India. It is estimated that India's current population of 1,200 million will continue to grow at the rate of 3-3.5% per annum. With the per capita waste generation increasing by 1.3% per annum, the yearly increase in waste generation is around 5 % annually. The government is under constant pressure to efficiently handle the ever growing amounts of solid waste and make cost effective changes. Added to constrained budget allotments in the solid waste sector, poor administrative management practices have been a focus of increasing concern (ERM, 2004). A review of literature of SWM in India highlights institutional/financial issues as the most important ones limiting improvements in SWM; Hanrahan et al (2006) specifically notes that "There is an urgent need for much improved medium term planning at the municipal and state level so that realistic investment projections can be developed and implemented." New methods for cost planning will support waste managers when faced with difficult decisions (Milke, 2006)

Statistical techniques such as multiple regression analysis are an estimation procedure that is used by some in the developed world to estimate costs of SWM. Multiple regression models are used to develop cost estimating relationships that are commonly called "Cost Functions" (CF). CF tie the cost or price of an item (eg a product, good, service, activity) to the cost driver (one or more independent variables) (Langfield-Smith et al).

Porter (2002) in his engaging book on the economics of waste shows how cost functions can be used by society to make decisions that are economically efficient. The Ramboll/COWI Joint venture (2002) have applied average cost functions to arrive at SWM investment options at the regional level in

Poland. Cost functions have been estimated for different waste treatment facilities (such as windrow composting, biogas plant, MRF, recycling, incineration, landfills etc) applicable to Europe. The values used to arrive at these cost functions have been obtained based on experience by COWI and information from various other facilities. The cost functions are in the form $y= m(xi)^{b}$ where y= total investment or O&M cost ; m and b = constants ; xi= design/actual capacity(in tons per year). D. Pangiaotakopoulos and co-workers have also been active in developing functions relating the cost of particular solid waste processes (eg, landfills) to size (Kitis, et al., 2007; Tsilemou and Pang., 2004; Tsilemou and Pang., 2006). This appears to be the first work on economy-of-scale factors for MSW since that of Wilson (1981). Although the work done by Clark(1971), DeGeare(1971), Moon(1994), Hirsch (1965) are mainly to predict collection costs and future generation rates of SWM, it provides evidence that the procedure could be used as a simple and quick planning tool. The work cited in MSW economics literature focus on specific regions in the developed world. There seems to be no effort cited in literature at providing generalised cost functions applicable to developing countries.

The objective of this paper is to provide an overview of cost analysis and planning of solid waste management in India .A simple methodology using CF to estimate cost changes that are likely to accompany service quality changes suitable for developing countries is also suggested using India as a case study.

2. Diversity within SW sector in India- How different is it from NZ?

India is the second most populous country in the world consisting of 28 states and seven union territories. The country is undergoing a phase of rapid urbanisation over recent years putting immense pressure on the infrastructure of the expanding cities. Urban Local Bodies [ULBs] are statutorily responsible for provision and maintenance of basic infrastructure and services in cities and towns. According to the 1991 Census of India, there are 3,255 ULBs in the country which are further classified into various sub-categories based on their civic status. In this paper the term 'municipality' will be used in general to describe ULBs or any of its sub-categories to avoid confusion. Solid waste management is one of the single largest activities undertaken by municipalities. Due to the vast diversity in terms of the demographics of India, the variety with respect to SW characteristics within this single country is huge. Table 1 below explains this diversity by comparing the socio-economic variables affecting SWM between a developed country such as NZ and a developing country such as India.

Table 1: Comparison of SW variables between NZ and India

Status	NZ	India
Population	Low	High
% Literacy	High	Low
Technology Level	High	Low
Per capita Income	High	Low
Social Diversity	Low	High
Urban-Rural Divide	Low	High
Labour cost	High	Low
Capital Investment	High	Low
Rule of Law	Good	Poor
SW characteristics	Similar	Variable

3. Cost Analysis of SWM for the Indian Scenario—How much does it currently cost??

To get an insight into the actual costs of SWM services in India, an attempt has been made to analyse the extensive cost data of SWM that was first published in 2005 by the National Institute of Urban

Affairs (NIUA), India in their report entitled "Status of Water Supply, Sanitation and Solid Waste Management in Urban India" and correlate them to the district population of India. After omitting missing values, the dataset used in this paper covers a sampled population of 132 million distributed in 268 cities out of close to a total of 700 districts in India. The sampled cities and towns in turn represent the entire country, i.e., the 28 States and 7 Union Territories.

A municipality's solid waste expenditure can be analyzed most simply by its average costs. Average cost requires that the cost of a service be divided by some metric, usually tons or number of persons. Boxplots are used in Figure 1 (a & b) to compare the average costs both in cost per capita (Figure 1a) and cost per ton (Figure 1b) over three population ranges (i.e Metropolitan[1], Class I, and Class II cities) using a five-number summary: the median, the 25th and 75th percentiles, and the minimum and maximum observed values, outliers and extreme values if any. Outliers and extreme values are given special attention because with a large dataset such as ours they are bound to exist due to problems such as incorrect data accounting by certain municipalities, population of extended city not taken into account etc, to name a few. Excluding outliers was quite confusing in this study as removing one outlier results in creating another due to the high scatter in the data (Data issues discussed separately in next section). Hence it was decided to retain outliers and all further analysis and model fitting was done using the complete dataset.

The unit costs mentioned here could be of interest not only because they offer a benchmark for comparing average costs internally between different population ranges within India but also because they can also be used to compare unit costs with other developing economies in the world. It also gives a quick measure to monitor costs over time. Through such monitoring, one can identify inefficiencies and set goals for productivity improvements.

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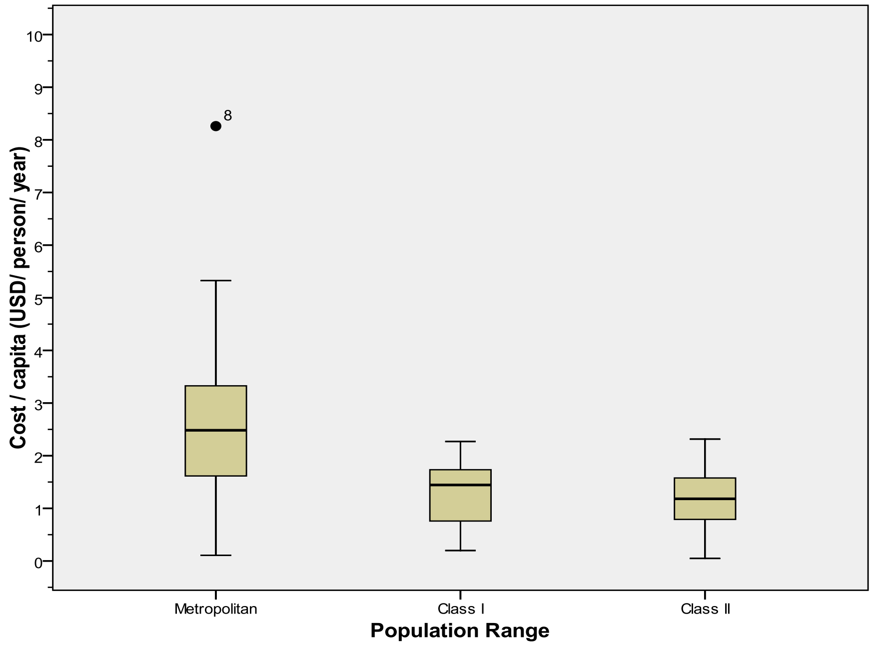
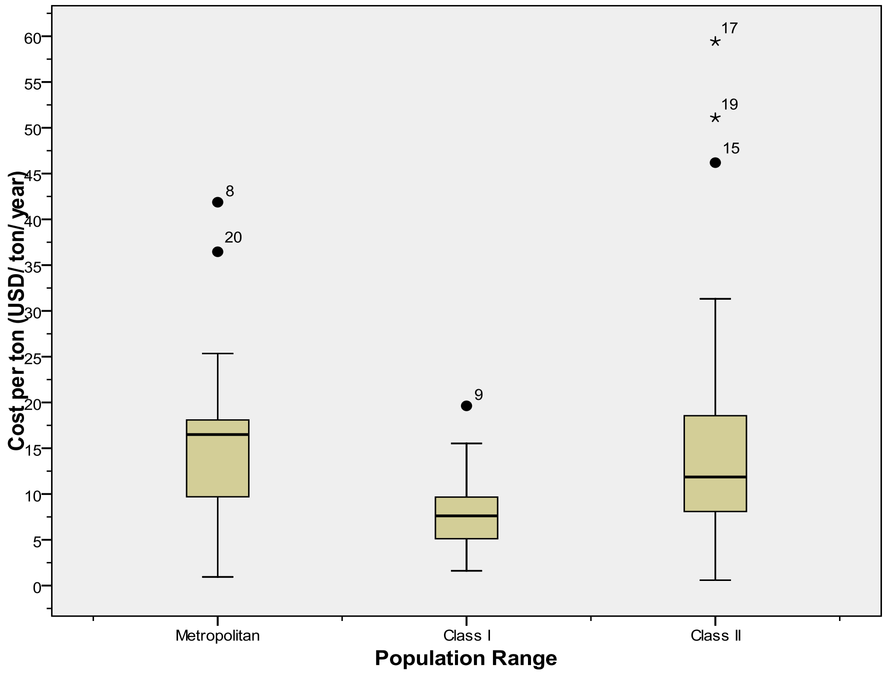
1 **Metropolitan Cities** - population> 1,000,000
Class I cities- 100,000 < population< 1,000,000
Class II cities- 50,000< population< 100,000

Figure 1: Statistical summary of average costs of SWM for Metropolitan, Class I and Class II cities, India. (P.S- Heavy Black Line inside box is the 50th percentile, or median; The lower and upper hinges, or box boundaries, mark the 25th and 75th percentiles of each distribution; Whiskers(the vertical lines ending in horizontal lines) are at the largest and smallest observed values; Outliers- O; Extreme values- *)



(a) Cost per Capita



(b) Cost per Ton

4. Realities and Challenges for an SWM planner

Funds for SWM in India are typically assigned as part of the annual municipal general budget (Zhu et al 2008). Municipalities receive income from various sources, central government, various NGOs, local taxes, with little income directly tied to SWM. They (municipalities) have to manage a number of civic services apart from SWM, the number of services increasing with the size of city. It has been observed that in smaller towns, where SWM is the main municipal service, municipalities spend up to 70% of their total budget on SWM (Hanrahan et al(2006), Zhu et al(2008)). The authors note that metropolitan cities on the other hand, due to wider resources base and responsibility to provide larger number of services such as water supply, sewerage, sanitation etc, spend only around 10% of their total budget on SWM. The provision of funds for solid waste management in India is commonly observed to be made on an adhoc basis, and not allotted on the basis of any cost estimate which is one of the biggest reasons for mismanagement of resources.

There are a large number of issues that compound the difficulties of decision making and cost planning in India. Data unavailability and inaccessibility is the most common complaint of SW planners Municipal planners require good quality data from the past to predict future costs for improvement and upgrading of existing services. Even when cost information are accessible, there is too often no way to cross-check the validity of the data obtained. As an example, we calculated the average cost per capita from three different but reliable sources, and found that there was a wide variation in the figures. Table 2 gives a comparison of the per capita expenditure on SWM across selected cities in India, each obtained from different sources.

- The Federation of Indian Chambers of Commerce and Industry (FICCI) survey revealed that Delhi has the highest per capita expenditure on solid waste management

- The National Institute of Urban Affairs (NIUA) conducted a study to assess the status of water supply, sanitation and solid waste management in 300 selected cities and towns and to estimate the funds required for full coverage of population by these services in the urban areas of the country.
- The National Solid Waste Association of India conducted a survey of various Indian districts. Their website contains a link that gives information from the survey for each district.

Table 2 : Per capita expenditure on SWM from various sources (1 NZD= Rupees(Rs) 33 approx in 2009)

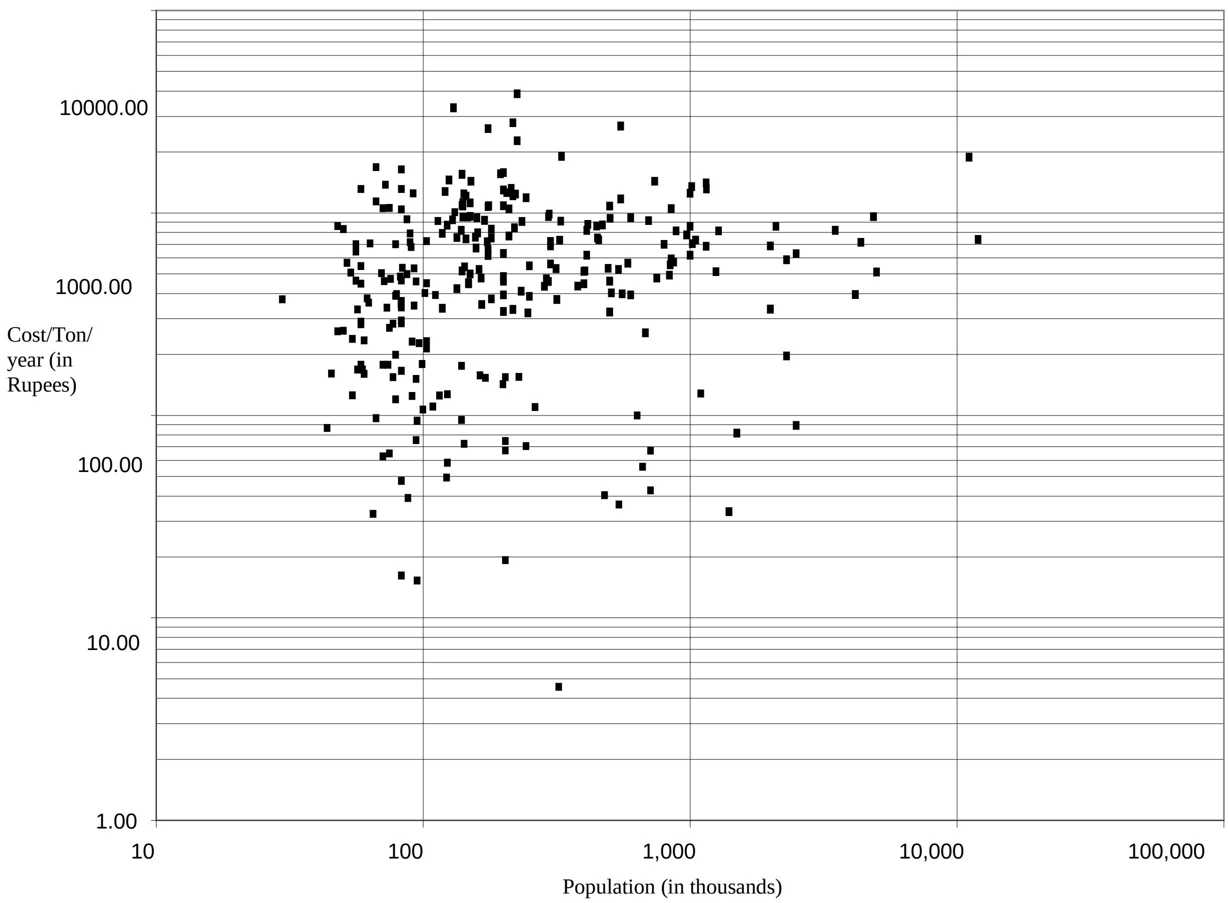
City	FICCI*	NIUA**	NSWAI***
Delhi	Rs 431	Rs 135	Rs 497
Mumbai	Rs 428	Rs 372	Rs 392
Jaipur	Rs 301	Rs 185	Rs 301
Chennai	Rs 295	Rs 150	Rs 295
Ludhiana	Rs 258	Rs 73	Rs 1

*FICCI - Federation of Indian Chambers of Commerce and Industry (2007)
**NIUA - National Institute of Urban Affairs (2005)
***NSWAI - National Solid Waste Association of India (2001)

Another potential problem with financial planning of SWM is that the existing cost data for SWM are highly scattered. To explain how wide this scatter could be, a graph of population versus cost per ton is plotted using the data from the NIUA (2005) for sampled districts across India. As seen from the Figure 2 below the cost per ton varies widely with the population. No trend can be observed and economies of scale do not seem to exist. Moreover this example is just from one source which might be biased or in error, though consistent. Possible reasons for the variation shown in the figure could be the variety with respect to the scope of wastes collected and services provided, the density of the population served, the % of MSW collected not being constant.

Figure 2: Double log graph of Population versus Cost/Ton, India 1999

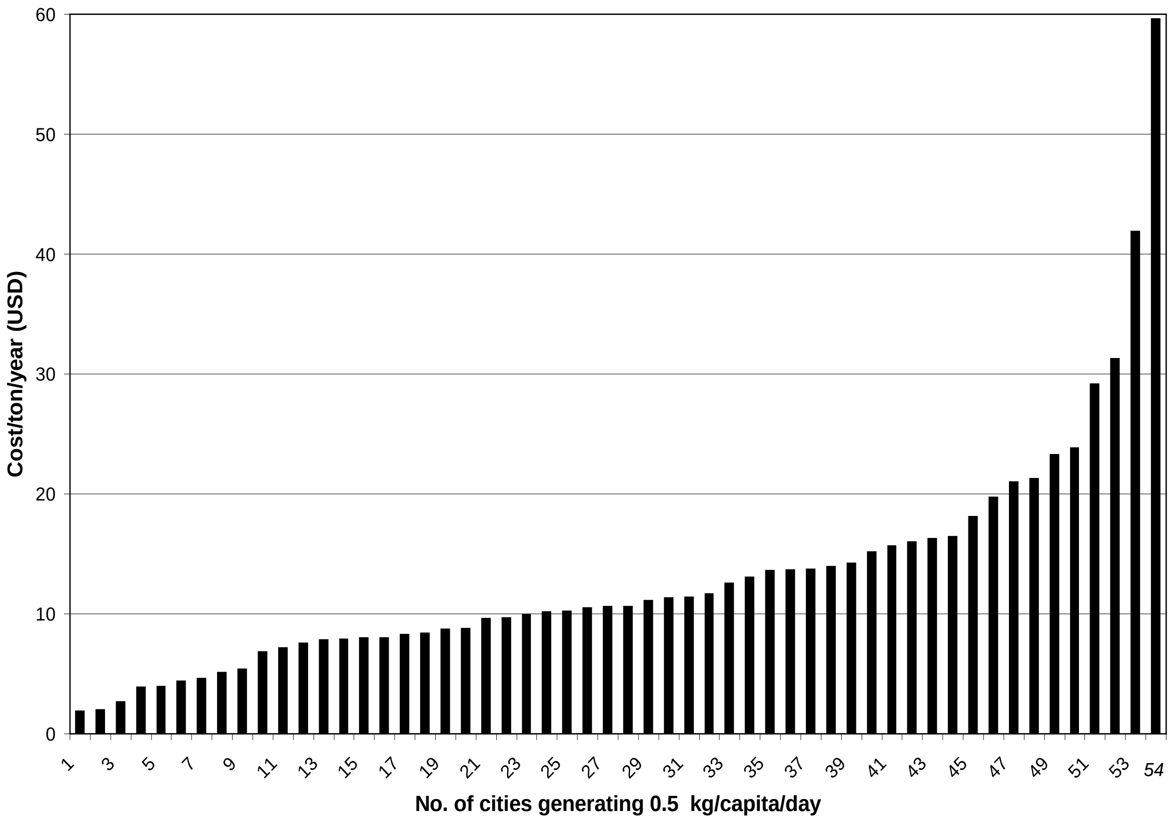
(Data Source: NIUA, 2005, 1 USD= Rs 45 approx in 2002)



We further investigated this scatter by studying the cost per ton values across cities with a constant waste generation rate. Since roughly more than 50% of the population spread across 54 cities with a total population of 65 Million generates 0.5kg per person per day only that particular section of data from the NIUA report was taken for a detailed analysis. In Figure 3 the cost per ton per year in USD across these individual cities (i.e only those cities that generate 0.5kg/person/day) is plotted. It was observed that the cost per ton per year varies from as low as USD 2 to USD 60 between cities. Such a comparison serves to highlight the vast variation in the costs per ton between cities even with a constant waste generation rate. Keeping these data issues in mind one can imagine the challenges that a SWM planner could face in these regions.

Figure 3: Variation of Cost per Ton of SWM across cities in India

(waste generation rate=0.5/kg/person/day)



5. Cost estimation and planning approaches: a brief review of literature and a suggested methodology

5.1.1 Review of Literature

Municipalities in India generally prepare their annual budgets using an incremental approach based on the previous year's budget (Zhu et al, 2007). Although there is no reliable established method to estimate costs for budget preparation, SW professionals have been recently focusing on this issue. Some yardsticks used to estimate costs are provided by Zhu et al(2007) in their book. The authors have considered the practices followed in India such as street sweeping, door to door collection etc and developed certain standards for eg. the number of street sweepers required per length of road, number of handcarts required for door to door collection depending on the population density of the area etc. These yardsticks have been used while preparing the five year (2005-2010) financial plan for improvement of solid waste management in the state of Rajasthan, India. The report by ministry of urban development in India (2004) contains a detailed cost estimate for a compost plant from 50tpd to 500tpd with component wise cost breakdown. Similar attempts for other aspects such as transportation, recycling, disposal are hard to find within the available literature.

5.2.2 A suggested methodology for cost estimation and planning in developing countries- The Cost Function approach

In India the solid waste services offered by municipalities of different states do not vary greatly within the country, and neither do the factors that affect the service. For example the costs(y) of door to door collection (which is a common service almost throughout the country) would depend on factors such as privatization(x1), collection frequency(x2), the number of housing units within the municipality jurisdiction(x3) etc. Although the magnitude of these factors may vary between cities, for example a particular city may privatize collection while the other does not, another city has a comparatively higher frequency of collection etc., the factors influencing the collection costs remain more or less the same. This allows for easy comparison between cities. Thus to evaluate city performance, a regression equation relating y to x1, x2, x3,….xn could be formulated. The coefficients of the x variables could provide useful information not only to analyze the current situation but also allow for future prediction. In other words it could aid in long term planning.

Stepwise Multiple Regression Analysis using SPSS 17 software has been used as a statistical inference in this paper to estimate constants in CF. The method is helpful to develop a simple linear equation between the "Total cost of SWM in India" (TC) and the variables affecting it for three population ranges (namely metropolitan, Class I and Class II cities). Two separate cost studies were performed as part of this study. One was to provide an insight into the (1) Per capita costs (i.e. total costs per person) and the other was an insight into the (2) Per tonnage costs (i.e. the total costs per ton). One can think of many factors that could possibly affect total expenditure. But only selected socio economic variables for which data were available from the NIUA report were used in this analysis. The following variables that were thought of as having an influence on total costs were used: x_1=Population Density, x_2= Waste Density, x_3=No. of vehicles used for transportation, x_4=Average trips per vehicle per day, x_5=Total number of staff employed, x_6=Frequency of collection, x_7=Privatization, x_8= Is medical waste collected and disposed separately. It is assumed that there is no change in labour costs, capital costs, land costs etc for the period of analysis. This seems justified as costs within cities within the same region for e.g. metropolitan cities for a given year will usually remain constant. And since several data points in the same time period are being studied, the emphasis is on understanding the difference in costs between regions, which was the aim of this study. Table 3 below summarises the cost functions for per capita and per tonnage cots obtained for the three population ranges.

Table 3: Summary of Cost functions for average total costs of SWM in India

Population Range	Total costs	Cost Determinants	Cost Function	R2
1. Metropolitan	Y_1=Cost per Capita	$x_1, x_2, x_3, x_4, x_5, x_6, x_7, x_8$	$Y_1= -1.759 + 1159.56\, x_5 + 39623.31\, x_3$	0.626
2. Class I	Y_1=Cost per Capita	$x_1, x_2, x_3, x_4, x_5, x_6, x_7, x_8$	$Y_1= 0.918 + 435.22\, x_5 - 0.456\, x_7 + 0.062\, x_2$	0.275
3. Class II	Y_1=Cost per Capita	$x_1, x_2, x_3, x_4, x_5, x_6, x_7, x_8$	$Y_1= - 0.007 + 838.44\, x_5 + 0.178\, x_2$	0.278

4. Metropolitan	Y_2=Cost per ton	$x_1, x_2, x_3, x_4, x_5, x_6, x_7, x_8$	$Y_2 = 4.58 + 858.09\, x_5$	0.200
5. Class I	Y_2=Cost per ton	$x_1, x_2, x_3, x_4, x_5, x_6, x_7, x_8$	$Y_2 = 8.63 + 1.65\, x_5 - 4.57\, x_7$	0.602
6. Class II	Y_2=Cost per ton	$x_1, x_2, x_3, x_4, x_5, x_6, x_7, x_8$	$Y_2 = -1.984 + 2.29\, x_5 - 0.001\, x_1$	0.666

x1=Population Density, x2= Waste Density, x3=No. of vehicles used for transportation, x4=Average trips per vehicle per day, x5=Total number of staff employed, x6=Frequency of collection, x7=Privatization, x8= Is medical waste collected and disposed separately?

The procedure for obtaining these cost functions using stepwise multiple regression can be found in most standard multiple regression textbooks and is beyond the scope of this paper. The results obtained so far are preliminary but give confidence as a way to evaluate highly scattered data. The models suggested here must be used with caution as the equations in Table 3 are NOT a perfect fit to the scattered data. Also, there are a number of sources of uncertainty and error such as doubts about accuracy and precision of the data, outliers etc. Nevertheless, it is hoped that the methodology of using cost functions for SWM cost planning suggested here will be a useful start and further study on this aspect is stimulated for those working in this area particularly in developing countries.

6. Conclusions

The paper provides a broad overview of cost planning of SWM services in developing countries with a case study on India. The scene in developing countries is very different from that of developed world with respect to the factors that affect solid waste management. This should be kept in mind while developing a methodology/procedure/ model for financial planning of SWM in developing countries.

The cost analysis taken up in this paper could help set solid waste cost benchmarks, even make comparisons with other developing economies that are performing better.

The main hindrance in cost planning seems to be associated with problems of cost data. There seem to be problems associated with data accuracy, high scatter and uneven budget allocations. As cost estimates and future planning is based on past data, first and foremost the importance of proper documentation and accounting of financial resources should be recognised. At the moment the complete picture of solid waste management is very confusing and solutions fuzzy to an SWM planner due to lack of these kinds of details.

A review of the cost estimation and planning literature suggests that developing cost functions is a simple and quick method to estimate costs for quality improvements. Unfortunately there is NO effort cited in the available literature that uses this method in developing countries. Average cost functions for different population ranges which relate the total cost as a function of the various variables affecting it are developed in this paper. The results obtained here is an attempt to take a step forward and use the cost function estimation method to plan costs in developing countries. Although the analysis, method and results are presented for the Indian scenario, it is not limited to one country. The overall objective is to use these methods of cost analysis and planning in any developing economy of the world.

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