Cost Estimation for Solid Waste Management in Industrialising Regions- Precedents, Problems and Prospects

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Abstract

The importance of cost planning for Solid Waste Management (SWM) in industrialising regions (IR) is not well recognised. The approaches used to estimate costs of SWM can broadly be classified into three categories- the unit cost method, benchmarking techniques and developing cost models using sub-approaches such as cost and production function analysis. These methods have been developed into computer programmes with varying functionality and utility. IR mostly use the unit cost and benchmarking approach to estimate their SWM costs. The models for cost estimation, on the other hand, are used at times in industrialised countries, but not in IR. Taken together, these approaches could be viewed as precedents that can be modified appropriately to suit waste management systems in IR. The main challenges (or problems) one might face while attempting to do so are a lack of cost data, and a lack of

quality for what data do exist. There are practical benefits to planners in IR where solid waste problems are critical and budgets are limited.

Keywords

review, financial planning, waste management costs, data quality, developing countries

1. Introduction

Perhaps the greatest SWM challenge faced by municipalities of IR is to achieve the most with limited funds. For example, a World Bank report on China (Hoornweg et al., 2005) on a lack of analysis into the "…cost-effectiveness in service delivery". A study of India (Hanrahan et al., 2006) highlights institutional/financial issues as the most important ones limiting improvements in SWM. Specifically, it 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."

Cost estimation is a tool used to evaluate resource requirements while being aware of associated uncertainties (Ostwald and McLaren, 2004). Improving cost estimating for solid waste management improves decision-making in various aspects of the service such as contracting for new equipment, or when evaluating changes to operating and maintenance strategies (Milke, 2006). The traditional form of a municipal budget consists of separate cost estimates of recurrent revenue, operating expenditures, and capital spending (Schaeffer, 2000). An estimate in turn comprises various components of SWM, including salaries, equipment, and the costs of routine maintenance. High quality cost estimates for SWM can not only help establish budgets, but also help defend budgets when attempting to improve the level of service.

Cost planning for SWM has been discussed in various forms (e.g., user charges, economic analysis and economies of scale) for industrialised regions. Some have focused primarily on quantitative approaches such as programming, optimisation techniques, statistical methods, and cost-benefit analyses (Clark et al., 1971; Chang and Wang, 1997; Huang et al., 2001), whereas others have focused on a qualitative analysis of costs of specific processes such as waste minimization, privatization, collection and disposal (Palmer and Walls, 1997; McDavid, 1985; Strathman et al., 1995; Jenkins, 1991) . For example, Wilson (1981) studied facility costs of waste disposal and suggested economy of scale factors for solid waste facilities. Porter (1996; 2002) emphasised the importance of focussing on solid waste economics while discussing ways to improve the service. Kinnaman and Fullerton (2001) compiled articles on the economics of residential SWM, including those that examine the external costs of municipal solid waste collection and disposal, the theoretical frameworks that can be used to model disposal decisions of households, and the empirical decisions that govern the selection of MSW policies. As an example application, the Seattle public utilities have developed a model called the Recycling Potential Assessment and System Analysis Model (RPA/SAM) to support several planning and policy initiatives (Bagby et al., 1998). The model uses previous cost estimates to forecast total system costs associated with SWM in Seattle.

Governments of IR are increasingly realising the importance of cost planning for SWM. For example, in India, the 12th Finance Commission (TFC) had recommended a grant of USD 550 million to Indian municipalities for the period 2005 to 2010 out of which at least 50%

was set aside for SWM (Appasamy and Nelliyat, 2007). Funding agencies expect well planned budgets before the start of the financial year. These can be provided by a municipality only if the true costs of the service are determined by consolidating costs from all departments engaged in managing the waste within a municipality. Unfortunately municipal budgets of IR are mostly based on projections from previous budgets or the need to pay salaries and purchase supplies and very rarely does a municipality know the actual cost of providing the service (Diaz et al., 1996; Bartone et al., 1990). Municipalities of IR often complain about lack of funds. They feel like they are not in a financial position to meet community needs (Zhu et al., 2008).

Cost models from industrialised countries could serve as precedents in IR. But a methodology to estimate costs of waste management that is applicable to IR requires a clear understanding of the differences between the two levels of industrialisation (Table 1).

Table 1: Differences between industrialised regions and IR in the context of SWM

Status	Industrialised	Industrialising
% Literacy	High	Low
Technology Level	High	Low
Per capita Income	High	Low
Social diversity and its effect on waste type	Low	High
Urban-Rural Divide	Low	High
Labour cost	High	Low
Capital Investment	High	Low
Quality of governance	Good	Poor
SW composition	Similar	Variable

Involvement of informal sector	Little /Nil	High

(Source: Authors)

The Strategic Planning Guide for Municipal Solid Waste Management prepared for the World Bank by Wilson et al.(2001) gives a detailed step-by-step procedure for economic evaluation of MSWM alternative strategies. An update of this work and extension of the financial chapters in the 2001 Strategic Planning Guide was prepared for the World Bank in the Middle East / North Africa region in 2005 by Faircloth et al. (2005). The finance and cost recovery sections of the guide contain tools, training material and case studies to aid municipalities and waste management agencies to effectively plan their finances. A book by UN- Habitat (Scheinberg et al., 2010b) is the most recent attempt to collect cost data along with other data and it compares 20 cities around the world. The book discusses in depth financial sustainability in SWM and its importance as a key governance feature. It looks at how the reference cities are counting costs and revenues, and how they are raising investments and managing their budgets. It is one of the few publications that reinforce the point made by the GTZ report (Scheinberg et al., 2010a) about the role of the informal sector (also referred to as scavengers or waste pickers (Wilson et al., 2006)) and its cost implications, a key difference between systems of IR and industrialised regions shown in Table 1. A summary of selected publications that have reported costs of SWM from IR is presented in Table 2.

Table 2: Costs of SWM from IR

Reference	Selected Case study locations	US$/tonne (except where noted)	Year of reported costs	Costs of Formal (F) or Informal (I) sector
Scheinberg	Belo Horizonte, Brazil	89/tonne	n.a	F

et al (2010b)	Delhi, India Quezon City, Phillipines	39/tonne 11/tonne		
GTZ/CWG (2007)	Cairo, Egypt Cluj, Romania Lusaka, Zambia	13/tonne(F), 4/tonne (I) 35/tonne (F), 7/tonne (I) 173/tonne (I), 7/tonne (I)	2006-2007	Both
Hanrahan et al (2006)	India	18/tonne – 36/tonne	2003	F
Koushki et al.(2004)	Kuwait	24/ tonne	n.a	F
Metin et al (2003)	Turkey	5/capita – 13/capita	n.a	F
Do an and Süleyman (2003)	Istanbul, Turkey	35/tonne	2001	F
Agunwamba et al (1998)	Onitsha, Nigeria	10/ tonne	1991	F

Note: n.a. – not available

The objective of this paper is to review current practices used to estimate costs of SWM in IR. If suitable precedents were not available from IR, examples are drawn from industrialised countries. The common problems facing a SWM planner in IR are discussed thereafter. An understanding of these problems suggests prospects for improved cost planning in IR.

2. Precedents

2.1 Unit Cost Method (UCM)

In the UCM, each activity (namely collection, transportation, treatment and disposal) is disaggregated into separate items such as salaries, consumables, fuel costs, and maintenance costs. Next the required quantity of each item is noted. Multiplying this with the cost per item or unit cost (developed from existing datasets or taken from price quotes), the total cost of each item is calculated. The overall cost of the service is then calculated by summing the total costs incurred by each item. The method can be used for setting up a new facility, buying additional resources, or used for budget preparations.

Table 3 shows the cost estimate developed for the state of Rajasthan (India) to improve SWM services in its 183 municipalities (Asnani, 2006).

Table 3: Capital cost estimate for modernisation of SWM in the state of Rajasthan, India, in 2006. Source: (www.almitrapatel.com/docs/132.doc, date of citation 23-03-2011.) (1 USD = 45 Indian Rupees in 2006).

Item no.	Item of Expenditure	Estimated Quantity	Unit Cost in Millions of Rupees(MRs)	Estimated cost in (MRs)
1	Public awareness	-		10.00
2	Capacity building	-		5.00
3	Containerized tricycles & wheelbarrows	15000	0.009	135.00
4	Secondary storage			
	7 m^3 containers	1000	0.04	40.00
	2.5 m^3 containers	2300	0.015	34.50
5	Transport vehicles			
	7 m^3 hydraulic container-lifting truck	97	1.4	135.80
	2.5 m^3 hydraulic container-lifting truck	97	1.1	106.70
	Tractor with hydraulic container-lifting device	140	0.75	105.00
6	Road sweepers	19	2.75	52.25
7	Construction of transfer stations	200	*	133.40
8	Large containers for transfer stations	50	0.15	7.50
9	Large hauling vehicles	30	2	60.00
10	Construction of compost plants	177	**	511.35

11	Engineered landfills				
	Large Landfill	40 Hectare	1	50	50.00
		16 Hectare	1	20	20.00
	Medium Landfill (20 acre)		11	10	110.00
	Small Landfill (10 acre)		58	5	290.00
12	Management Information System (Improved accounting system using GIS, pro-formas for collecting cost information)				0.50
	GRAND TOTAL				**1807.00**

* The cost of transfer stations in the state of Rajasthan in 2006 prices @ 0.5 MRs/municipality in the130 municipalities having populations < 50000, 0.8 MRs/ municipality in the 39 municipalities having populations between 50,000 and 100,000 and 1.2 MRs in the 14 municipalities having populations > 100, 000, amounts to 113 MRs. The O&M cost is estimated at 20.4 MRs amounting the total cost to 133.40 MRs.
** It is estimated that the cost of construction of a compost plant excluding the cost of land would be 5MRs per 100,000 population. Towns having population < 100,000 lac should opt for vermi-composting at 6.25MRs for a design population of 100,000

The UCM to estimate costs of SWM is simple to prepare, is reliable due to its top down approach and is easy to understand. The method being a deterministic approach to cost estimation means that the independent variable(s) are more or less a definitive measure of the item being estimated and hence this methodology is not subject to significant conjecture (Christensen and Dysert, 2003).

Although the method is straightforward in principle it can be laborious in application. The UCM requires robust documentation so the quantity of each cost component is reliable. The level of detail in decomposing into tasks will vary considerably from one estimate to another. If used for forecasting, it requires a good estimate of the number of units that will be required. Proper documentation can be difficult due to problems of poor accounting procedures and changing conditions of a city.

In addition, the UCM faces many difficulties because of its reliance on appropriate unit costs. Inflation can be easily overlooked with the UCM, and must be accounted for. The UCM assumes that cost data are available and complete, which is not always true, and incomplete cost data sets can lead to biased estimates. Furthermore, variability in unit costs may arise because different standards are required within a system (eg, daily collection in commercial zones, alternate day collection in residential zones), and these variations often need close consideration when developing cost estimates.

Overall, the reliability of the method is a function of the reliability of the cost model. Because of the complexities in modelling large systems, other methods can provide more readily accessible guidance on costs. Nevertheless, because of its simplicity and clear assumptions, the unit cost method is the most commonly used method to estimate costs of SWM worldwide.

2.2 Benchmarking

A quick way to make a reasonable cost estimate is to use actual cost data from a similar organization that has made a change of the type under consideration—this is commonly called benchmarking. The Department of Urban Services, Canberra, Australia in their 1999-2000 budgets have used benchmarking analysis to estimate costs of waste management and recycling. To estimate landfill costs in the 1999-2000 budget, comparative information has been taken using the 1998-99 budget information from a similar jurisdiction (www.treasury.act.gov.au, date of citation- 23/03/2011) In another report, the Vermont Department of Environmental Conservation's Solid Waste Program (DSM, 2005), used the data from the residential and commercial price survey findings in 1999 to estimate the total solid waste and recycling collection and disposal costs for planning purposes in 2005. The 1999 data served as a benchmark cost and were used for comparison of SWM prices statewide and by region, and is also expected to serve as a benchmark for future comparisons.

The World Bank report by Hanrahan et al (2006) summarizes the findings of a year-long analytical work conducted by the World Bank, in two Indian states and three hill towns. To improve understanding of costs of MSW management, a spreadsheet was modelled in collaboration with municipal staff in the study locations. Also presented in the report are approximate expenditure benchmarks across municipalities (1 USD= 45 Indian Rupees (INR) in 2006)

- Collection of waste: 300-400 INR/tonne
- Transport of waste: 300-400 INR/tonne
- Treatment/disposal (average costs, excluding land): 400-600 INR/tonne
- Total cost of waste collected and disposed: 1000-1200 INR/tonne

Due to difficulties in normalizing the data obtained from different cities, costs were reported in ranges and individual cities were not identified. (Hanrahan et al., 2006).

Benchmark costs need to include all costs. The UNEP's (2004) 'Introductory Guide for Decision-makers' mentions that the total annual costs, i.e. operating cost plus the annual payback for capital investments, should be estimated since collection equipment, landfills and other installations needed in an integrated waste management system have various lifetimes and depreciation periods. It suggests estimating costs separately for general administrative initiatives (such as issuing permits, legislation), and specific waste processing activities (such as recycling, composting) for different waste streams (such as putrescible, organic or inorganic, recyclable and non-recyclable, hazardous). According to the authors, this should make it possible to keep track of the economic costs of reaching objectives. It may also make it possible to compare the costs of the existing waste management system with the future costs of the new waste management plan(UNEP, 2004).

Benchmark costs can be reported on a per capita, per mass, or per volume basis, and there can be difficulties in applying these to new situations without more information. For example a benchmark collection cost of $30/tonne could be for a waste with a density of 300 kg/m3 and generated at a rate of 0.1 tonne/person-year. However, in many IR, densities of collected waste can reach 600 kg/m3, and a generation rate of 0.2 tonne/person-year (Diaz et al., 1996) would imply the same volume of waste collected. Because of this, normalised benchmark costs should also provide values for tonnes/person-year and waste densities to ensure appropriate comparisons are made.

As an example of the use of benchmarks, Zhu (2008) provides benchmarks (Table 4) for assessing the needs of funds for Indian SWM services. Their book provides advice to improve costing and budgeting of SWM services. For example, for waste collection a common existing system involves having concrete street bins as central collection points, to which individual householders take their waste. To estimate the cost of an upgrade to door-to-door collection, one would use the benchmarks provided in Table 4.

Table 4: Benchmarks for estimating costs of SWM in India (Zhu et al., 2008) (Prices in 2006; 1 USD= 45 Indian Rupees (INR) in 2006)

Door to Door Collection

- One containerised tricycle/handcart per 1000 persons.
- Cost of Tricycle: INR 6500 –7500 (Inclusive of containers); Handcart: INR 4000 – 5000 ; Handcarts and Tricycles have a useful life of 3-5 years).
- One sanitation worker to cover 200 houses /shops in 4 hours serving a population of 1000 each day (Labour costs for one full time worker is INR 6000 per month).
- One part time supervisor per 25 sanitation workers. (Labour costs for one part time supervisor is INR. 3500 to INR. 4500 per month per worker).

Street Sweeping

- Each street sweeper to be given individual containerized handcart / tricycle (for costs see above).
- One person per
  - 300 to 350 meters of road length (in High Density Areas)
  - 500 to 600 meters of road length (in Medium Density Areas)
  - 650 to 750 meters of road length (in Low Density Area)
- Labour costs same as D-T-D collection.

Secondary Storage

- Provide a pair of metallic containers (one for organics collected from households and the other for street sweepings) of 3.0 m^3 -7.5 m^3, with four containers per square km of the city area or one container per 5000 - 7500 population. (A 3 m^3

will cost INR 19-20,000 and 7.5 m^3 will cost INR 45,000).

Transportation

- 1 vehicle per 10 containers (Costs of container lifting vehicle is INR 1 million for 7 m^3 containers and INR 850,000 for 3 m^3 containers ; a smaller tractor with container lifting device costs INR 525,000).
- Additional 25-30% for standby vehicles.
- One driver and one sanitary worker per vehicle (Labour costs= INR 6000/month for a full time worker or INR 3500/ month for part time worker.

Processing/ Composting

- INR 12 million for populations under 50,000.
- INR 20 million for populations up to 100,000.
- INR 34 million for populations up to 200,000.

Disposal in an engineered landfill

- Capital cost of INR 100- 150 per cubic metre (includes construction cost, weighbridge, office accommodation).
- Operating cost of INR 200- 1100 per metric tonne of waste depending on size of landfill.

Benchmarks might not allow fair comparisons. A lack of full-cost accounting is one potential limitation, and capital costs could be neglected in some benchmark costs. Inadequacies in the database (such as no year of the costs) may mean that this approach should not be used. Limitations can exist because the scope or quality of services provided could vary greatly. Even without these issues, the costs associated with a specific item (eg, a landfill) are site-specific, reflecting availability of local facilities, salaries and land prices . There could be bias in a dataset that would cloud the value of its use. A budget may have been under accounted to make it look good for easy approval of funds or it could be over accounted for managers to show at a later stage that they performed well by cutting costs in the long run.

A lack of reliable information on costs can be exacerbated if responsibility for the different waste management tasks is spread widely across a number of divisions. This is a particularly large issue in IR where both the informal sector and non-profit organisations can be operating in addition to the municipality in SWM, and so are not considered by a municipality when developing benchmarks. The savings to the municipality by these other sectors is hard to estimate and so adjustments of benchmarks based on a municipality's data is challenging. The only attempt at reporting benchmark figures of informal sector costs in IR is the report by GTZ/CWG (Scheinberg et al., 2010a); the reader is referred to section 3.2.1 for more discussion. Costs of other such smaller organisations if overlooked have potential to cause serious discrepancies when using benchmarked values for cost planning purposes.

Another issue with the benchmark technique is potential bias in the dataset. A budget may have been under-accounted to make it look good for easy approval of funds or it could be over-accounted for managers to show at a later stage that they performed well by cutting costs in the long run. Such biased costs, if used as benchmarks to estimate costs elsewhere, could lead to serious deficiencies in long term planning. Data issues related to cost estimation for SWM are discussed further in section three.

The use of benchmarks assumes that they represent good practice, and that the location under consideration should manage solid waste following this exemplar. This can lead to the difficulty that the estimated cost reflects what the community should spend and not what they do or will spend. Hence even though benchmarking costs of SWM is one of the most common approaches, it is unreliable if not done with appropriate quality assurance systems. The systems being compared need to be understood in terms of their characteristics such as the individual components of a system and the standards under which they operate.

2.3 Cost Modelling

2.3.1 Production and Cost Functions

Economists refer to the relationship between the output of a process and the necessary input resources as a production function (Fullerton and Kinnaman, 1995; Wohl and Hendrickson, 1984). The amount of output is the maximum, or best, output achievable for a given set of acceptable inputs. For solid waste management, a production function would relate the specific factors that a manager could use to provide the service, for example, number of trucks and number of employees. The term cost function is used to describe more broadly the relationship of cost to variables. Cost functions relate the cost of solid waste management to production factors or to variables such as population density or the type of service provided (door-to-door or community collection).

Cost and production functions can be expressed in terms of a variety of input variables (trucks, employees, frequency of collection, total tonnes collected), and can be either linear or non-linear functions. If the only input variable considered is a scale variable, such as tonnes/year, then the function describes the economy-of-scale effect for that cost. The effect can show increasing returns of scale where negatively-sloped, constant returns to scale where horizontal and decreasing returns where positively sloped (Figure 1). The coefficients in cost and production functions are typically estimated empirically based on the use of regression techniques applied to available data sets.

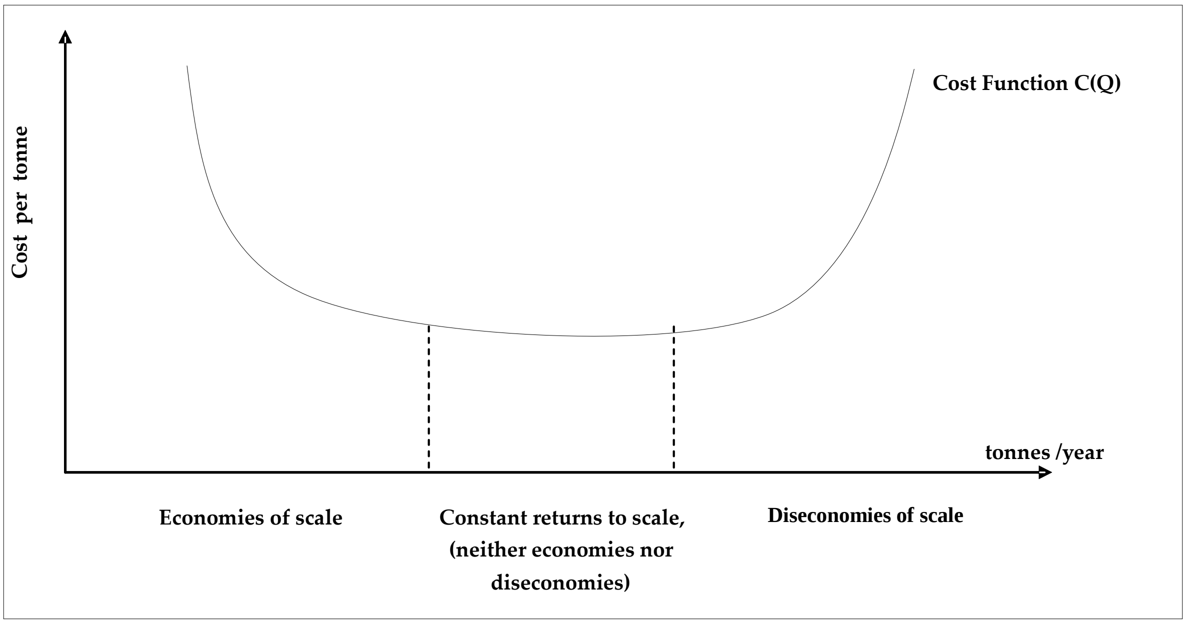


Figure 1: Returns to Scale (Increasing, Decreasing and Constant)

Cost and production functions have a number of uses. They help a planner in evaluating performance at one location by allowing comparison. They allow for future predictions such as examining the cost implications of increasing the frequency of waste collection from once to twice a day. They allow one to draw conclusions concerning economies of scale. They can be used to find what set of inputs will minimise system costs for a given level of service.

Moreno-Sanchez and Maldonado (2006) built upon their earlier works and performed a numerical simulation using production functions for waste pickers using data from Bogota in Columbia. Their results were aimed at suggesting optimal policy instruments like consumption tax, recycling subsidy and extraction tax to help policymakers in incorporating the informal sector into the formal waste management system. Although no other instances of cost or production functions for IR were found in available literature, there have been a number of applications of cost/production functions to industrialised country settings. The Ramboll/COWI Joint venture (2002) has applied average cost functions to arrive at SWM investment options at the regional level in Poland. They estimated cost functions 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 facilities. The cost functions are in the form $y = m(x_i)^b$ where y= total investment or O&M cost; m and b = constants; x_i= design/actual capacity (in tonnes per year). Callan and Thomas (2001) present an economics literature review of solid waste disposal and recycling services in industrialised countries. Based on their specification of costs, they employed Zellner's (1962) seemingly unrelated regression (SUR) procedure to estimate a two equation cost function model. D. Pangiaotakopoulos and co-workers have been active in developing functions relating the cost of particular solid waste processes (eg, landfills) to size (Kitis et al., 2007; Tsilemou and Panagiotakopoulos, 2004 ; Tsilemou and Panagiotakopoulos, 2006). This appears to be the first work on economy-of-scale factors for SWM since that of Wilson (1981).

Early researchers such as Hirsch (1965) presented residential refuse collection cost models. A number of variables were analyzed using production functions and cost functions. Multiple regression and correlation techniques were applied to 24 municipalities in the St Louis City-County area in 1960 (Hirsch, 1965). The data did not reveal significant scale economies but the authors commented that it cannot be considered conclusive, mainly because municipal and collection area boundaries may not have coincided in all cases.

Clark (1971) suggested a stepwise regression analysis approach as a planning tool for arriving at cost functions for metropolitan SWM in 20 Ohio municipalities. A total of eight variables hypothesized as having an influence on cost were analyzed. The study concluded that financial arrangement (i.e., who pays for the service), collection frequency and pickup location (curb or back of house) are the only significant factors affecting costs of collection. The effect of population density and waste collected per unit areas were not considered in the analysis. Economies of scale were not investigated in this study.

Stevens (1978) analyzed the costs of waste collection using data of 340 public and private firms collecting refuse in the United States during 1974-75. These were analysed for population ranges lesser than 20,000, 30-50000 and greater than 50000. The author first formulates a production function $Q=A\ L^{\alpha}K^{\beta}$ where Q is the total quantity of refuse collected; A is a constant representing the state of technology and the joint effect of a set of variables influencing the production process (such as weather conditions) which must be held constant in a cross section study; L is the total quantity of labour inputs; K is the total quantity of capital inputs; and α and β are distribution parameters representing the share of output attributable to labour and capital, respectively, and where $0 < \alpha, \beta < 1$. The objective was to estimate the total costs of refuse collected at households as a function of market structure, refuse per household, the frequency and location of pickup, population density and variation in temperature. It was concluded that strong economies of scale in refuse collection exist only for communities up to 50,000 in population. This author's discussion of how production functions give rise to neoclassical economic cost functions is a particularly good introduction for readers who may not be immediately familiar with the neoclassical economic theory of the firm and of market structures.

The most recent works by De Jaeger and co-workers (De Jaeger et al., 2011) and Weng and co-workers (Weng and Fujiwara, 2011) feature cost estimation methodologies using cost and production functions. The authors recommend using the data envelopment analysis technique and the econometric modelling technique respectively to handle growing complexities and uncertainties in modern waste management systems. For more industrialised country examples on cost function analyses for solid waste management using multivariable regression analysis the reader is referred to the article by Bel and Mur (2009) which contains a concise review of existing literature on the topic of cost functions for SWM.

2.3.2 System Models

A number of models focus on economic aspects and their main purpose is to minimise costs using linear programming or other optimization techniques. The advanced optimization modelling framework developed by Xu et al. (2010) uses a combination of existing linear programming and optimisation methods to appropriately balance uncertain aspects of the waste management decision process. To demonstrate the applicability of their method a hypothetical SWM case of three municipalities was chosen, and two treatment options (landfilling and incineration) were evaluated, to arrive at a long term cost planning model.

The purpose of the Local Authority Waste Recycling Recovery and Disposal (LAWRRD) model (Brown et al., 2006) is to estimate the minimum local waste management costs throughout England, along with the flows of materials and the facilities needed for waste treatment to meet the EU Landfill Directive targets and increased rates of recycling and recovery. LAWRRD is a costs-driven model that takes each administrative region, finds its minimum cost system subject to various constraints, and then aggregates overall costs. It models waste management by taking input data on waste production, numbers of actual or planned facilities from each local authority in turn and then summing the relevant outputs to develop a picture representing England as a whole.

The GIGO program developed at UC Davis aims to minimise SWM costs in a wide variety of locations of industrialised regions (Anex et al., 1996). Similarly, FEASIBLE (a freeware that can be obtained through the web pages of the OECD (www.oecd.org, date of citation: 23-03-2011), DEPA/DANCEE (www.mst.dk, date of citation: 23-03-2011) and the developers, COWI Ltd. (www.cowi.dk, date of citation- 23-03-2011)) was developed to support municipal solid waste, water and wastewater financing strategies for the European Union, Central and Eastern Europe and the former Soviet Union. FEASIBLE uses built-in cost functions (referred to as ‘expenditure functions’ in the software’s user manual), developed by COWI, to generate investment, operating, and maintenance costs. These are based on scenarios or inputs describing the existing physical infrastructure and the future physical infrastructure, and applied to selected case studies (Pesko et al., 2003)

The COSEPRE (costs of urban cleaning services) program developed by Sandoval et al (PAHO, 2001) allows cost evaluation of scenarios and facilitates the calculation of the annual and unit costs per service, based on information provided by the user. It determines the costs of each service only when a complete full cost accounting is already available to the user.

There are a number of review papers on SWM models which summarise the current work in this field (Beigl et al., 2008; MacDonald, 1996; Morrissey and Browne, 2004), hence this approach is not discussed in detail in this paper.

One major challenge when using system models is the difficulty in generalising them to other situations. It can be difficult to obtain the underlying cost functions, and even more difficult to know how they have been developed and their potential applicability. More significant for this review is an acknowledgment that the values used in industrialised countries are so removed from circumstances in IR (Jain et al., 2005; Rathi, 2006) as to be unusable. Future research is needed to analyse the values used by various models relevant to industrialised countries.

3. Problems

IR use either the UCM or benchmarking approach to estimate costs of SWM. Both these approaches rely heavily on good cost data. A common woe cited in the literature on SWM in IR is the lack of cost data for high quality planning (Agunwamba et al., 1998; Hoornweg et al., 2005; Visvanathan and Trankler, 2003; Idris et al., 2004). Although none of the authors in the available literature have thoroughly examined the topic of data limitations with respect to SWM, they state that data issues compound the difficulties of decision making and modelling. Cost estimation and planning needs to be informed by past data.

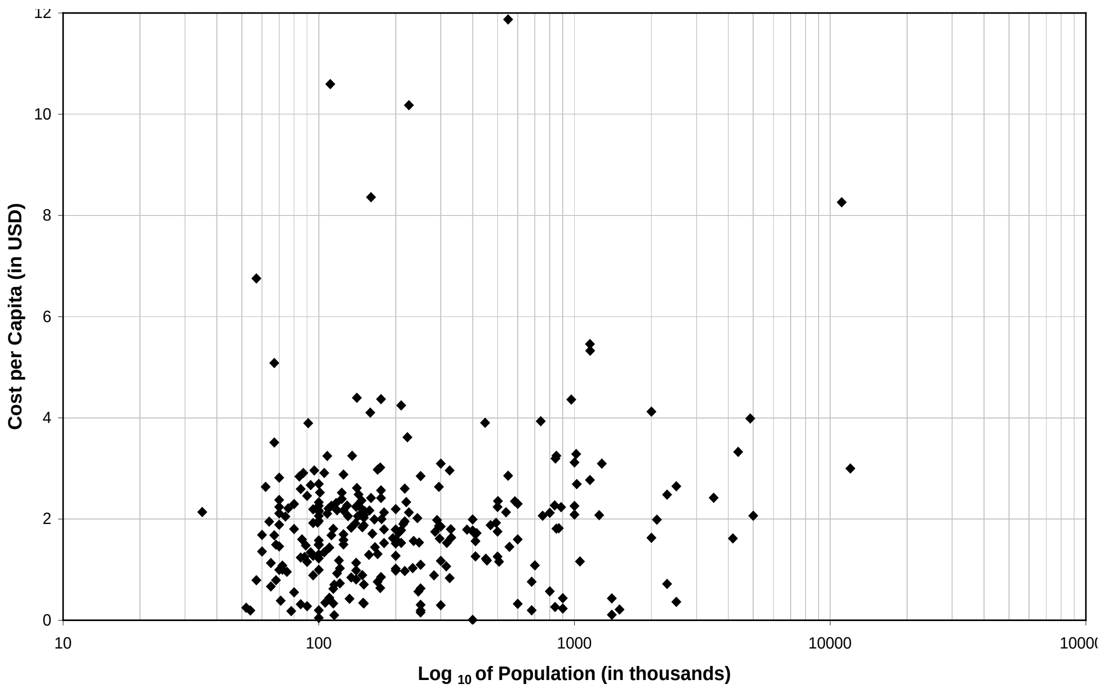
The objective of this section is to review the challenges that planners need to overcome while attempting to estimate costs of SWM in IR. An Indian case study is studied as an example as it well represents the complex nature of waste management systems of a typical IR due to its economic, social and cultural diversity.

3.1. Data Analysis

The National Institute of Urban Affairs in India (NIUA, 2005) conducted a study in 1999 to assess the status of water supply, sanitation and SWM in roughly 300 selected cities and towns in India and estimated the funds required for full coverage of population by these services in the urban areas of the country.

Figure 2 shows that cost per person varies widely with population in India; no trend can be observed and economies of scale do not seem to exist.

Figure 2: Graph of population vs. cost/person, India 1999 (Data Source: NIUA (2005))



The above example was from a single source hence it was decided to cross-check the validity of the data from other sources. Table 5 gives a comparison of the per capita expenditure on SWM across select cities, from different sources.

Table 5 : Per capita expenditure in Indian Rupees (INR) per annum on SWM from various Indian sources (1 USD = 45 INR in 2006)

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

*FICCI -Federation of Indian Chambers of Commerce and Industry (FICCI, 2007) (Population estimate- 2001 census, year of cost not documented but assumed here to be same as population estimate)
**NIUA - National Institute of Urban Affairs (NIUA, 2005)(Population and Cost in 1999)
***NSWAI - National Solid Waste Association of India (www.nswai.com, date of citation: 23-03-2011) (Population estimate as per 2001 census, year of cost not documented but assumed to be 2001)

3.2 Data Issues

The data values are estimated in Figure 2 and Table 5 are arrived at using either the UCM or benchmarking methods, or a combination of both. The joint impact of the following data issues is the probable cause of variability associated with SWM data shown in the figure and the table.

3.2.1 Variety in scope of service

SWM in India involves a complex mixture of various organizations. The formal ones include municipal organizations and private contractors. In addition, there are non-governmental organizations (NGOs), community based organizations (CBOs) and resident welfare organizations (RWOs) that employ the informal sector to carry out this activity. Finally, there is an independently working informal sector that can collect waste and participate in resource recovery, sometimes without payment, and outside of normal methods of data collection.

Wider scope amounts to greater confusion when cost data are presented. At first glance, at say the city of Ludhiana in Table 5, it would seem that only one source has rightly reported the city's per capita costs, and two source must be in error. But in fact it is possible that each source has reported costs of a different organization involved in managing Ludhiana's waste, thus making comparisons misleading. For example, the highest cost of INR 258/capita reported by FICCI could be the overall cost collated for both formal and informal sector. Whereas the cost reported by NIUA (INR 73/capita) is known to be the cost incurred by the formal sector only i.e, of the municipality and its private contractor (NIUA, 2005).The cost reported by NSWAI of INR 1/capita is possibly the cost incurred by the municipality alone, i.e., excluding costs to private contractor and informal sector. A planner looking to predict costs for an estimated population of 5 million for Ludhiana will not be able to choose the best cost per person estimate between the three sources in Table 5 unless he/she has a clear understanding of all the organizations involved in managing Ludhiana's waste.

Another issue confronting a SW planner is that the scope of activities can vary from city to city. The cost per capita is arrived at by dividing a municipality's net cost of collection through disposal by the population it services. Comparing the cost per capita values, it is quite possible that one city has a compost/landfill facility, which incurs a higher net cost than a city that open dumps its waste.

Sometimes, the scope of SWM activities varies within the same city. Consider the example of Delhi in Table 5- the areas that are covered by the New Delhi Municipal Committee of Delhi have door-to-door collection, while the areas covered by the Municipal Corporation of Delhi bring their waste to community bins ((Scheinberg et al., 2010b). The mixed system in Delhi could have an effect on the net cost (which in turn affects average cost per capita) making it lower compared to Chennai which has completely adopted door to door collection in all its areas.

An issue with cost data on SWM from IR is that they are generally available as municipality SWM expenditures or percentages of overall municipal budget (Scheinberg et al., 2010b). Costs of private contractors are not well documented. Getting cost data on the informal sector is even harder due to their flexible and informal systems of operation. The only attempt at providing cost information about the informal sector available in the literature is the report by GTZ/CWG (Scheinberg et al., 2010a) which finds that the overall system costs or costs per tonne would rise in developing counties if not for the informal sector recycling activities. The cost per tonne of waste operations (mainly collection and operating costs) of the informal sector vary from 3-90 Euros/tonne in the six cities of IR analysed in the report. The figures reported are a useful start to future studies regarding informal sector costs and also allow for comparison with the formal sector.

3.2.2 Variety in quality of service

Costs of SWM are best analyzed when divided by some metric, usually tonnes or number of persons (DPPEA, 1997). Differences in quality of service could have an effect when using normalizing metrics. A potential problem that could affect the proper evaluation of per capita costs in Figure 2 is large uncollected parts of the city. For example, let us assume that the cost per capita for servicing a city was 2.07 USD in 1991, found by dividing an expenditure of 10.35 million incurred on SWM in 1999 by the municipality, by a 1991 census population of 5 million. But if the municipality had actually serviced only half the city's population, i.e., 2.5 million and not 5 million in 1999, the cost per person served would have been 4.07 USD. Supposing that the incorrect value of 2.07 USD/ person were used to estimate costs for an extension of service to an extra 1 million population, the budget could be underestimated by 2 million USD.

Similarly, if costs were measured on a per tonne basis, a potential problem affecting costs per tonne could be that the parts of the city where waste are not collected are also the parts where it is expensive to provide services, possibly underestimating the true costs per tonne if the whole city were to be serviced.

Getting a good measure of the amount of waste collected and the population serviced are crucial data needed to estimate costs in a consistent form. Even after accounting for parts of the city serviced, a distinction is needed between costs per tonne generated and costs per tonne collected or disposed. The UN-Habitat book (Scheinberg et al., 2010b) showed that 16 out of 20 cities that were surveyed diverted a minimum of 65% of waste going to their formal disposal sites, due to informal sector recycling. This can have an effect on the cost/tonne collected or generated which is useful for planning purposes, and has potential to distort cost estimates.

3.2.3 Differences in cost accounting systems

A number of sources in literature (Hanrahan et al., 2006; Scheinberg et al., 2010b; Wilson et al., 2001; Zhu et al., 2008; Metin et al., 2003; Zurbrugg, 2002; Schübeler et al., 1996; Idris et al., 2004; Bartone et al., 1990; Wilson, 2007) discuss fuzziness in cost accounting procedures as a major issue limiting improvements in SWM in IR. One example is whether or not equipment purchase is accounted for as a capital cost or an ongoing depreciated cost. Others are if costs are before or after tax, and whether costs of overheads, operating costs, fuel costs ,benefits to employees are included or not. A final example relevant to the NIUA dataset is the definition of 'salary and wages'. Under this component if one municipality accounted for certain expenses such as reimbursement of medical expenses, welfare expenses, uniform, payment to casual staff, travel concession, and hospitalization benefits, adding 20% more to its 'salary and wages' component, the overall cost per capita could easily be higher compared to another municipality that did not report these costs as part of its 'salary and wages' component. Differences in accounting systems are not always clear and can make it difficult to compare costs between organizations.

The Strategic Planning Guide for Municipal SWM prepared for the World Bank by Wilson, Whiteman and Tormin (2001) and an update of this work for the Middle East / North Africa region in 2005 (Faircloth et al., 2005) note that municipalities of IR are not able to clearly distinguish cost components (capital, operating, O&M) in accounting data. The guidelines suggests that recurrent costs incurred through operating municipal SWM should include 1) direct operational expenditures such as wages and maintenance 2) provisions for accrued expenses and liabilities such as employee pensions, obligations, insurance and 3) annual amortization charges to recover the capital assets over their useful life such as loan interest and depreciation (ELARD, 2005)

3.2.4 Cost adjustments

Too often in literature the year in which costs are documented is not mentioned, making comparisons difficult, like in the case of Table 5 in which the year of costs were not clearly reported by NSWAI (www.nswai.com, date of citation: 23-03-2011) and FICCI (2007).

When the year of reported costs is known, there is always a need to adjust costs obtained to account for inflation for one currency, and to account for the variation in value between currencies. For example, in Figure 2, to arrive at costs per capita, the 1997-98 SWM expenditure of the municipalities from the NIUA report was brought to April 1, 1999 (the start of the financial year in India) prices using rates of inflation from the Labour Bureau, Government of India, to make it consistent with the population estimate provided in the report. An approximate exchange rate of 1USD =INR 45 in 1999 was assumed. Choosing an appropriate exchange rate for cost comparisons that best accounts for differences in SWM prices between countries can be a challenge. It is often unclear what an appropriate currency exchange would be when IR sometimes have strict currency exchange rules. Also, when exchange rates vary depending on what was bought or sold (multiple exchange rates), particularly on capital goods such as high end trucks used to transport waste, it is hard to select a particular exchange rate. Another approach would be to use the ‘purchasing power parity’ or PPP exchange rate as it converts the data into a common currency and values it at the same price levels, making the process of cost comparisons between countries simpler . PPPs are estimates derived from the relative price levels in different countries and reflect the rate at which currencies can be converted to purchase equivalent goods and services (Vachris and Thomas, 1999). For example, if the PPP exchange rate is 9.3 Indian Rupees per USD, the average monthly wage of a collection worker in India which is 6000 Indian Rupees in terms of its purchasing power in India, is equivalent to 645 USD. If this is to be compared to a Chinese collection workers salary of 800 Renminbi (with PPP exchange rate 1USD is equivalent to 3.462 Renminbi), the equivalent in USD would be 231. Although using the PPP exchange rate is not so common and is currently being used for topics concerning poverty issues, it seems a valuable alternative when cost comparisons for SWM are concerned.

3.2.5 Scarcity in public domain

The UN-Habitat study (Scheinberg et al., 2010b) is a recent wide-ranging attempt to collate SWM data (financial and other) for 20 cities on a comparable basis. It is acknowledged that such an attempt was difficult. The NIUA (2005) work is another example, but there appear to be no other studies, which reflects the scarcity of SWM data. The NIUA study took 10 years to complete because of issues such as election schedules, non-response to questionnaires by municipalities, and follow-up required for incomplete data (NIUA, 2005). In IR municipal websites do not give sufficient information on the costs of projects undertaken. Overall, financial matters are rarely discussed in the public domain.

The United Nations report (Habitat, 2001) states that "one of the key challenges faced by municipalities of IR is to reduce corruption". One might speculate that inaccessibility of cost data could also be due to municipal authorities fearing that the discrepancies of the system (corruption, low wage rates paid for labor) could be exposed if such information becomes accessible or published.

4. Prospects

Studies indicate that local conditions, management strategies, composition and characteristics of SWM are similar in IR. (Zurbrugg, 2002; Diaz et al., 1999; Beede and Bloom, 1995; Savage, 1998), Better cost estimation for SWM could lead the way to creating a SWM database with country- specific unit cost estimates, similar to what has been developed by WHO (World Health Organisation) researchers (Adam et al, 2002) for healthcare management, another public service with characteristics similar to SWM (Cossu, 2011).

Improved cost accounting in municipalities of IR has the potential to improve cost planning. Unfortunately as critical as this activity is, cost estimation of SWM must frequently be done without the benefit of good historical data or adequate sample sizes. In such cases one could attempt to study a similar locality, city or town which is managing its waste well, and develop benchmarks from its experience to estimate costs (Zhu et al., 2008). Activity-specific cost functions could be developed from a series of well chosen benchmarks.

Hybrid cost estimation methods attempt to combine aspects of benchmarks with aspects of the unit cost method. For example, the informal sector study of Scheinberg et al. (2010a) estimates costs by developing a series of cost components based on activities, and then developing a complete set of the number of each unit used. Rather than rely on estimated local costs as would be done under a pure UCM, they use benchmark unit costs based on their previous experience in IR   There is further potential to improve cost estimation methods by using selective benchmark values, rather than gross cost benchmarks (eg, cost/ton, or cost/capita-year).

Developing cost functions for SWM will be central to improved cost planning for IR. It would help in making cost comparisons between cities, in predicting future costs, and identifying key variables affecting costs. While regional differences and technologies yield different average costs, the way in which production functions, and consequent cost functions, are modelled is invariant across regions. The lack of cost functions for SWM was highlighted by Pearce (2005) as a significant hindrance to improved efficiency. This is even more critical in IR where problems of waste are severe and finances are constrained. A step by step development of cost function for SWM using an Indian case study can be found in Parthan et al (in press). Further research is needed to manage the differences between regions, and the quality of data, within cost models developed using cost functions.

Few advances have been made in estimating direct monetary costs of SWM in IR. When such estimates are available, they can be used as inputs to deterministic analysis methods, such as calculating net present value or internal rate of return, as suggested by the Environmental Resources Management's (ERM) Strategic Planning Guide for MSWM designed for the World Bank (Wilson et al., 2001).

New methods for cost planning will support waste managers when faced with difficult decisions (Milke, 2006). Improved cost estimates would lead to easier cost accounting and so fewer misspent resources, leading to an improvement in service delivery in IR. More importantly, it would increase the confidence of national governments and aid agencies that an investment of financial resources will be spent well. Development of better cost planning for industrialising regions has the potential to open the door to creative systems for improving SWM there, much as carbon accounting has allowed carbon trading systems between industrialised and IR. Such schemes would require a high quality system for estimating costs to achieve specific performance levels, which does not now exist.

5. Conclusions

The number of publications on cost estimation and planning for SWM with specific reference to IR is limited indicating that much more attention needs to be paid on this topic. The examples of data issues provided for IR indicate the nature of challenges faced by a SWM planner and are not intended to criticize the system.

A good cost planning approach for SWM is one that allows for improvements in SWM practices to achieve a certain level of performance while efficiently using available data and financial resources. In IR the performance level is governed by how well an increasingly migrant urban population is being covered by the service. The usability of existing cost estimation methods for SWM cost planning seems limited for two reasons. First, each method (UCM, benchmarking and cost modelling) has its drawbacks when applied to IR. Second, the underlying complexities resulting from multiple stakeholders involved in managing waste in IR (municipalities, private contractors, non-governmental organisations, community based organisations, resident welfare organisations, informal sector) makes cost estimation difficult.

An integrated approach that combines the potential of the UCM, benchmarking technique and cost modelling approach using cost functions could be a way towards improving cost planning in IR. A recommendation would be to firstly map out the flow of material and costs, through different stages and including all providers, in the existing SWM system (along the lines of a process flow diagram as suggested by Scheinberg et al (2010b). Cost functions based on the unit cost method for each stage in the system could then be developed. This could help determine existing costs or rates, which would most likely be different for different providers of the service in IR., for example, with informal recycling, there is the income to account for. These costs or rates could be used as future benchmarks and could also be useful to compare with benchmarks from other cities. The developed activity-wise cost functions could be aggregated into an overall system model. Such a model when calibrated for geographic areas where there are good data could be used for municipalities or areas with limited data. In addition, development of cost models may assist in understanding data deficiencies.

An improvement in cost estimation and planning in this very important public service could greatly help in upgrading existing systems in a cost efficient manner during a process of industrialisation. There is great potential for innovative publishable research on the topic, and high long-term research impact can be expected in addition to the important practical benefits.

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