Economics of Municipal Solid Waste Management: A Case Study of Delhi

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MASTER OF PHILOSOPHY

By

Biswadeep Basu

CENTRE FOR ECONOMIC STUDIES & PLANNING
SCHOOL OF SOCIAL SCIENCES
JAWAHARLAL NEHRU UNIVERSITY
NEW DELHI – 110067, INDIA
July, 2005

CENTRE FOR ECONOMIC STUDIES & PLANNING
SCHOOL OF SOCIAL SCIENCES
JAWAHARLAL NEHRU UNIVERSITY
NEW DELHI-110067, INDIA

*This is to certify that the dissertation entitled "**ECONOMICS OF MUNICIPAL SOLID WASTE MANAGEMENT: A CASE STUDY OF DELHI**", submitted by **Biswadeep Basu** in partial fulfillment for the award of the degree of **Master of Philosophy (M.Phil)** of this university, is his original work and may be placed before the examiners for evaluation.*

This dissertation has not been submitted for the award of any other degrees of this university or of any other university.

Dated: 28th July, 2005.

Chairperson

Jayati Ghosh

(Prof. Jayati Ghosh)

Supervisor

N Rao

(Prof. D. N. Rao)

Phone : 91-11-26717676, 26717557 Ext. 4421/26704421 Cable : JAYENU Fax : 91-11-26717603, 26717585, 26717586.

To

My Parents

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CHAPTER I

Introduction

With the advent of civilisation the most direct impact goes to the environmental standard. Previously people were not so much bothered about its degradation as it was not that much prominent. But, over the time, with new scientific inventions and scarcity of resources resulting from burgeoning population level, it has become a debatable issue that how far should we progress in order to maintain environmental standards within the acceptable limit. Considering these fact, experts started thinking about various environmental issues like air pollution, water pollution, climate change, loss of biodiversity etc. Solid waste management is another important matter of concern as it is very prominent particularly in developed countries where free space for disposing off those wastes have been reducing every day as a result of increasing trend in urbanisation. That is why since long many developed countries have been taking various measures to tackle this problem. There, they manage this problem by a well organised municipal working system and that run successfully due to well aware peoples' participation and strong financial back up. Municipalities / Municipal Corporations collect revenue through various kinds of tax rates. Individuals pay according to their waste generation and sometimes there have some provisions of getting subsidy in return of recycling activities. Economists have argued for several economic measures considering household utility and production functions along with intrinsic human nature. But these things are applicable only in advanced countries as they have proper system of running municipal activities like collection, transportation, processing, recycling and disposal and maintaining records for the years. On the basis of well maintained records for years, experts can suggest the suitable economic measure with which the system can run in a better way.

But things are almost reverse in developing countries like ours. Here, unfortunately, no such proper measures have been taken to manage this problem. Bhinde & Sundaresan explored this field elaborately in Indian

perspective as early as 1973. They examined collection efficiency, physical and chemical characteristics of wastes for different cities and provided a proper guideline about how to manage the problem of solid waste. Things, till date, have not done to a satisfactory extent that results in unnecessary though avoidable nuisance created by this. People even the authorities, with some few exceptions, are not getting the importance of the level of the problem though with burgeoning population, India has been experiencing a rapid rate of urbanisation. These will surely increase the municipal solid waste generation and if not managed properly, it will affect the environment to a greater extent. One of the main reasons for not tackling the problem effectively is financial constraint faced by the municipalities/municipal corporations. Under the circumstances, it becomes necessary to implement some economic instruments in order to finance the associated expenditure. But before doing any such things we have to have the information regarding the amount of waste generation along with its physical and chemical characteristics so that appropriate economic instrument can be applied considering the trend and pattern of the waste.

Objectives:

Given the issues like rapid urbanisation, changing life styles that tilting towards western culture, scarcity of available land for waste disposal, paucity of funds necessary for running municipal services properly, in this study our objective is to show the extent of the problem i.e. what would be the level of wastes generation in future to provide an idea about the extent of the problem in future so that necessary measures can be taken to manage it. Along with that, we will also show the relative dependence of the factors like population, level of per capita income and public expenditure related to waste management activities such as public awareness campaigning, setting up of waste treatment plants, allocating more budget for mechanised version of collection and related services, etc. on the generation of municipal solid waste at the aggregate level so that policy makers can emphasise those factors as an effective step of managing municipal solid waste management. One thing should be kept in mind that in this study we have concentrated on various aspects of municipal solid waste

only. Throughout this study wherever we mention the name - solid waste, we basically mean to say about municipal solid waste.

This chapter, along with this introduction and objectives of the study, is arranged in the following manner: in section A, various types of solid waste has been discussed; next section gives us an idea about solid waste management with an outline of its functional elements; section C deals the problem in case of developing countries. Following section discusses the importance of the issue in viewing the population trend along with fast change in urban life style as a result of consumerism. The environmental impact and health hazards associated with municipal solid waste have been discussed in section E and in section F, respectively.

A. Types of Solid Waste:

Solid waste basically consists of three parts – industrial solid waste, agricultural solid waste and municipal solid waste.

Industrial Solid Waste:

Solid waste generated from industrial sources are heterogeneous ranging from inert organics as in those produced in mining, collieries, to organics from those producing basic consumer products and may include even hazardous waste as in nuclear industry. Industrial solid waste can be grouped into two parts: non-hazardous and hazardous. The non-hazardous part can either be bio-degradable or non-biodegradable.

Biodegradable[1] wastes mainly come from food processing units, slaughter houses and cotton ginning & textile mills. Whereas non-biodegradable wastes come from colliery wastes, solid wastes from refineries, steel plants, thermal power plants, lead-zinc industry, paper industry, aluminum industry etc. hazardous wastes are generated from urban and industrial sources contain some toxic ingredients. The substances are considered as toxic when the concentration exists a particular value below which it may not endanger public health. Hazardous wastes can originate from synthetic items, metals, salts,

[1] a substance that can be broken down by micro-organisms

acids and alkalies along with organic solvent, explosive wastes and radioactive wastes.

Agricultural Solid Waste:

Agricultural solid waste are not that much harmful to the environment as industrial wastes are, because almost all agricultural wastes are organic in nature. If there is adequate provision of dumping those organic wastes then it hardly creates any problem, except methane emission. In developing countries because of sufficient dumping place in rural areas where agricultural wastes usually generate, problems related to this is still negligible. But it can also be minimised by taking timely steps like setting of energy treatment plant to generate energy from waste.

Municipal Solid Waste:

Waste generated in residential and commercial areas are termed as municipal waste. In addition to the waste generated in residential and commercial premises, the waste from streets is also included in municipal solid wastes (MSW). Street wastes fall into three main categories natural, road traffic and behavioral.

The dust blown from unused land and roads, dead and decaying vegetation, seeds originating from avenue trees or blown from marginal areas, which can not be controlled.

Road traffic wastes originate from wear and tear of road surface and that from transport vehicles. The motor vehicles which moving on the roads discharges petrol oil and at times spill their contents on roads.

Waste originate from substances thrown by pedestrian or by persons using the streets and from the adjoining houses, shops and other premises which spill out due to improper storage are termed as behavioral wastes.

Demolition and construction wastes are not normally expected to be dumped in the collection bin and the agencies are required to bring the material directly to specific disposal sites.

Apart from these there is another type of solid waste viz. hospital wastes, which though supposed to be collected separately, is with some few exceptions a

part of municipal solid waste in developing countries like ours, as hospitals and nursing homes spill out their wastes due to improper storage, management and facilities.

The quantity of municipal solid waste generated depends upon a number of factors such as food habits, standard of loving, degree of commercial and industrial activities, cultural traditions, socio-economic and climate conditions. Refuse characteristics vary not only from city to city but even within the same city itself and also seasonally. Main physical ingredients of MSW are paper, plastic, glass, metals, organic components, inert and ash etc. The physical analysis on the basis of proportional weight can help in choosing the appropriate system for collection and processing.

A large organic content indicates the necessity of frequent collection and removal. Moreover, since organic content absorbs maximum moisture, it is better to compost this part for further use. Larger amount of paper indicates that the waste can be thermally treated. Plastics in high concentration indicate possible problems in their disposal as plastics take thousand of years to deplete properly into the soil. A large percentage of ash indicates that putrefaction will not readily occur and that collection frequency could be less. In such a case sanitary landfill would be better method. But the problem is that the intrinsic value of the material for further use has not been fully recognised even today. Except some developed countries, the expenditure incurred for managing solid waste is not at all significant so that a proper disposal or reuse method can be applied through resource allocation.

In many developing countries, particularly in India, the collection, transport, processing and disposal of solid waste(which is a highly visible and important municipal service) are considered as social activities for which they use to charge a nominal flat fee (which is basically a lump-sum tax) for financing the cost associated with it. Due to this option people who generate more wastes are not penalised with higher taxes causing revenue loss for the municipalities/municipal corporations. Given the large expenditure involved with collection, transport, processing and disposal, those authorities can not provide sufficient service to do those activities due to financial constraint. Pile of wastes lying here and there is a very common scene in our country and the

irony is that citizens get accustomed to live with this nuisance, though avoidable. The attention provided falls far short of the known and desired practice which could be attributed to public apathy, entrenched habits and traditions and vested interest leading to ineffective management. With suitable modifications in management, techniques applied in developed countries can also be applied to developing countries. To some extent, in few municipal areas in India, such an effort has been applied. But to deal this problem properly more and more municipal areas should adopt advanced technology that are used in developed countries taking into account the physical and chemical characteristics of wastes, degree of industrial and economic development, financial constraint and socio-cultural aspects.

B. Municipal Solid Waste Management:

It involves management of activities associated with generation, storage, collection, transfer and transport, processing and disposal of solid waste which is environmentally compatible with regard to economic, aesthetics, energy and conservation principle. It also includes planning, organisation, administration, financial, legal and engineering aspects involving interdisciplinary relationships[2]. Let us have a brief overview of the functional elements of the municipal solid waste management.

Outline of Functional Elements:

Generation – quantity and quality of wastes vary from place to place. Though wastes generated consistently in residential areas throughout the years but it varies significantly over the season both in commercial and industrial areas.

Storage – the generated wastes are stored within the premises in commercial and industrial areas; whereas in residential areas, occupants take it and transfer to commercial storage bins.

Collection – in India and also in other developing countries primary collection is the most common way of collecting waste. Here a large number of workers with adequate equipments collect wastes from roadside to the community bins and

[2] Composition and disposal options of MSW for different countries are given in Table 3.10 and 3.11

in urban area they follow house-to-house collection method as city people are comparatively more aware about this problem.

Transportation – the material collected in community dustbins is transferred to transport vehicles for transport to the processing or disposal site. In India, a common scene is that, garbage falls from a fully loaded truck used for transport to the roads thereby, causing the roads to look ugly. Though there is a provision of putting cover over the truck to stop garbage falling from t, people are reluctant to maintain this properly.

Processing and Recovery – a large quantity of waste has to be processed before suitable disposal to reduce its potential nuisance value. Occasionally recovery of useful constituents is also carried out as an independent process.

Disposal – the waste may come for disposal either directly after its transportation, or after processing. Disposal could be on land or water logged areas for reclamation.

Different functions stated above are interdependent and could be better managed by a system approach. Disposal method costing less may not always be the best as that may be offset by higher transport or processing costs.

Thus managing municipal solid waste requires a thorough involvement of both individuals and the concerning authority. The dimension of the problem varies from one country to another, even from one place to another. Third world countries, with their paucity of funds, face several problems in managing MSW than their developed counterparts.

C. Problems in Developing Countries:

The characteristics of wastes in developing countries differ considerably from that in developed countries due to difference in food habits, culture, traditions and socio-economic aspects. In developing countries the organic matter is higher due to the use of fresh and unprocessed vegetables and has high moisture content. Unpaved roads and seasonal variation in climatic conditions lead to increase the ash and soil content thus increasing the density of the waste. While in developed countries due to exposure to industrial and urban activities for a log time, the people became aware of this problem much earlier. There authorities do the necessary activities through an effective working

system of taxation and its realisation, which became possible by introducing suitable legislation and regulations. In developing countries, like India, these things are yet to be done. Except some few metropolises, there are no provisions of collecting garbage from door-to-door on a regular manner. As a result heaps of garbage lying beside the roads. Here municipal authorities use to charge a flat fee for the activities like collection, transportation, disposal and treatment etc. and industries are subject to under command and control regime where the have to pay some penalties for breaking the standard though penalties are insensitive to the extent of violation.

There should be enough awareness in peoples' mind as well as in policy makers' considering the importance of the problem regarding environmental impact and health hazards that could be caused by it.

D. Importance of the Problem:

Generation of solid waste in particular MSW is an obvious part of civil society. Earlier people did not bother about the disposal off solid waste as plenty of lands were available that time, as well as physical and chemical characteristics of wastes were not that much harmful as it is today. With the increasing trend in urbanisation and significant change in consumption pattern, municipal solid waste management has become a serious challenge to any urban locality. In rural areas, mainly in the developing world, due to low standard of living people seldom use packaged foods; so the proportion of non biodegradable matter in waste is less in those areas.

Moreover usually there are some free lands within the house premises where people can afford to dump their waste which contains organic matter as the major part that resembles with the consumption pattern of the rural people. So managing municipal solid wastes in rural areas is not at all a big deal. The problem mainly lies in the urban part. In developed countries, where standard of living of even poor people are far higher than most of the people in developing nations, people have been facing this problem since long as urbanisation rate is much higher there. Moreover, with prominence of consumerism at its fullest extent in that part of the world, people there use to consume maximum of their commodity bundle as packaged food that results in higher proportion of non

biodegradable part in the waste. The problem of managing municipal solid waste is mainly associated with urban areas where free plots available for land filling is getting reduced day by day largely due to rapid rate of urbanisation.

Along with this, effects of growing economy are reflected through the life style of urban people mainly for which, they opt for more packaged foods that resembles with their improved standard of living. This trend started in capitalist countries 3-4 decades ago. As a result they started thinking of managing MSW quite earlier. Now they are in a better position as far as the management of this problem is concerned. Through suitable legislation and regulations along with effective implementing skills they have introduced various forms of measures that include improved collection efficiency, source separation, introduction of recycling technology, composting, incineration, sanitary landfill etc. India being a developing nation is lagging behind of these steps even though the problem is not negligible. India with a mixed economy framework is one of the prime targets of multinational companies to reap the benefit of globalisation. Moreover, after the economic liberalisation in 1991, with some exceptional downtrends, Indian economy has shown satisfactory performance. As a result standard of living of the urban people in particular, has increased remarkably. They have become familiar with using more packaged items that result in higher proportion of plastics and papers in end use. On the other hand, driven by the search for job and socio-economic attraction, people use to migrate from rural to urban areas. Moreover, level of population has increased irrespective of places. As an obvious result of perpetual population growth along with high rate of migration, major cities in India have been facing significant increase in urbanisation over the last one and half decades. This trend is more acute in metropolitan cities where due to higher employment opportunities millions of people migrate from country sides throughout the year. Along with that, India being the second most popular country keeps on producing significant number of heads each year and according to the experts by the year 2051, following the present trend India will be the most popular country (World Bank, 2003).

So given this burgeoning trend in population along with high level of migration, city area has increased a lot by acquiring free plots around the city. Previously it was the free plots where city wastes were dumped. But given the

scarcity of vacant plots, the scenes that tones of garbage are pilling up here and there have become very common.

Considering the environmental impact and health hazards associated with this issue the present trend could not be tolerated for long at least by considering betterment of the society. Here the importance of the concept municipal solid waste management comes into the picture. In the next two sections we will discuss the environmental impact and health hazards associated with MSW.

E. Environmental Impacts:

In our country a common practice is that people burn roadside garbage in order to reduce its volume. That garbage basically consists of papers, plastics and other synthetic items along with some organic items. Bulks of the organic items are either collected by the authority for disposal off or get rotten over time. Spontaneous combustion of wastes in disposal sites causes heavy air pollution. Various toxic elements come out with smoke from the combustion and they are highly harmful to our health. Moreover, due to moisture content in organic wastes, carbon monoxide comes out as a result of incomplete oxidisation.

Methane is another harmful gas that originates from organic wastes which are remained unprocessed for a long time and contributes substantially to the greenhouse effect unless it is tapped for energy. Individual do suffer from various problems related to lungs due to these gases. Improper selection of dumping sites can also incur environmental costs. Sometimes water lands are chosen for disposal sites that might cause biodiversity loss due to the destruction of living beings under the water. Garbage itself has an aesthetic cost. Lying of garbage along the roadside for a long time causes sight pollution for the people who pass through that place. Improper selection of dumping sites may cause ground water pollution through leachate[3].

Wastes may also run off during heavy rain and cause surface water pollution. Apart from these there are several diseases that occur due to improper disposal of MSW and that appear even fatal in some cases.

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[3] liquid that accumulates dissolved or suspended materials as it permeates the solid waste in the land fill

F. Health Hazards:

Uncollected waste in developing countries creates serious problem to public health in many cities causing many diseases including often fatal water borne diseases such as cholera and dysentery. Venkateswaran (1994) attributed the outbreak of plague in Surat in India to the uncontrolled fermentation of waste which created conditions favourable to the breeding and growth of rodents and insects that acted as vectors of diseases. A similar study by WHO 1995, observed in 1994 that 616960 cases of cholera resulting in 4389 deaths were reported in Angola, the Democratic Republic of

Congo, Malawi, Mozambique and Tanzania. At least 600 deaths occurred out of 171000 cases of dysentery in Malawi, Mozambique and Zimbabwe (Holloway 1995). This can be linked to the facts that in northern Africa at least 20 percent and as much as 80 percent of urban solid wastes are disposed off by dumping in open spaces. Research studies also suggest that contamination of ground water by disease causing organisms from water seeping through dumps is likely to include the viruses of hepatitis, poliomyelitis and gastroenteritis. Thus such water contamination may have long run health effects apart from the more immediate ones like dysentery and cholera.

Health hazards are also imparted to specific group of people like rag pickers. They come in direct contact with waste and remain exposed off for hours. These workers suffer from skin diseases, respiratory and ophthalmic diseases and from ulcers and infected wounds (Sarkar, 2003). A study in Ahmedabad (Venkateswaran, 1994) found that more than 15 percent of sweepers suffer from tuberculosis – a rate three times higher than the national average. The problem is acute among the workers in this field because they are seldom protected by occupational health and safety measures and have to work without any protecting equipment. In an extensive study on waste pickers of Delhi, Sarkar (2003) argued that, since these people belong to the poorest and most deprived section of the urban population, under nutrition, growth retardation, anemia, tuberculosis and other bacterial and parasitic diseases are very common among them. In her study, it is reported that around 61 percent of waste pickers get injured due to hazardous working conditions in the form of cuts and bruises from glass, metal sharps, broken bottles etc. 27 percent of waste pickers who

collect medical waste sustain injuries syringes, sharp and broken bottles and ampules. Moreover, there can also be air borne diseases that make allergic disorders of the respiratory tract of the workers and chemical poisoning pesticides, lead batteries, etc.

The magnitude of the problem is particularly alarming in case of developing countries where municipal collection of solid waste is impeded by paucity of fund and technological capacity. For instance, it is estimated that between 15 to 20 percent of the total municipal budget is used for tackling solid waste problems in developing countries like India (Mathur, 1994 and Singh, 2001). The inadequacy is shown by the fact that up to 30 percent of solid waste disposal is left uncollected in various metropolis of the country (Gerlagh *et. al.* 1999). The areas, which are not serviced, are left with clogged sewers and litters which create serious health problems for the resident population (India Today, 1994). The gaps in waste disposal services also relate to the availability of infrastructure.

Therefore, the problem relating to the municipal solid waste management should be considered with adequate importance by the civil society and general people as well to restrict the extent of this problem within affordable limit. In doing so, this study attempts to project the future extent of the aggregate municipal solid waste generation on the basis of a case study for the city Delhi, India, so that it can be helpful to the policy makers to adopt necessary measures to tackle the problem efficiently for the particular city as well as for other cities of more or less common characteristics.

The study is arranged as follows: chapter 2 reviews various literatures regarding trend, pattern and possible economic instruments that can be applied to collect the necessary revenues to overcome the financial scarcity. There we also discuss about the relative merits and demerits of those instruments. Apart from that use of other options like the 'command and control' policy and negotiation between polluter and local authority are also explained there in detail.

The next chapter is about an overview of MSW management in case of India as a whole. There we discuss about the issues of municipal solid waste management in India and what are the hindrances of running a well performed

municipal system. Moreover, we also talk about the problem of MSW management for other developing countries with special reference to some advanced countries where possible.

Chapter 4 is the most important part of this study and that deals with the problem for the city Delhi. Considering the case study for this particular city we have shown the relative dependence of MSW generation at the aggregate level on factors like population, per capita income and public expenditure related to waste management activities. Along with that a projection of the aggregate generation of end use for the future years is also discussed by giving in detail description of the methodology adopted and analysis derived thereafter.

In chapter 5, policy measures that should be taken by the concerning authority with different perspectives such as economic, administrative, social and environmental for an efficient management of municipal solid waste is discussed. Finally, the conclusions derived form the discussion of the whole study is given at the last section of this chapter.

Chapter II

Review of Literature

Introduction:

The problem associated with solid waste began at the dawn of civilisation when man started living in groups or societies in settled communities. Prior to this the waste of primitive societies could readily be absorbed and dissipated by natural process because population densities were small and the available lands for disposal were relatively large. But after that with the gradual increase in population and economic growth, managing the daily waste became a serious problem to the society. Considering this, experts have argued regarding managing the problem in an efficient manner in which wastes should be disposed of either through land filling or be used for further uses through recycling, composting, incineration etc. But paucity of fund is the main problem in opting of various methods of managing waste. Ethically it is the local municipal authority, which is liable of providing municipal services to the people living within its territory. Given the financial constraint they are not always able to provide sufficient services to the society in dealing this problem that results in improper disposal of municipal solid waste through which several environmental and health related problems emerge.

In viewing this economists have suggested some measures of financing the costs associated with the municipal solid waste management so that the municipal authority can have the sufficient revenue to provide adequate services to the society. There can be imposition of rules and regulations by the government as a part of the command and control (CAC) policy; or applying economic instruments like advance disposal fee, deposit refund system and recycling subsidy. But before going into detail discussion of these instruments we should have a proper idea about the components that consists of municipal solid waste and also of the volume of the waste and of its trend in future otherwise determining the optimal policy will be a difficult task to do.

This chapter is arranged as follows: in section A we discuss about the source classification of waste; the next section focuses on the trends and pattern in

waste generation. Following this, section C covers options and policies for waste management. A detail discussion about the economic instruments for managing MSW is carried on in section D. Section E discusses about the other instrument viz. CAC.

A. Source Classification of Waste:

Knowledge regarding various sources of MSW should be the primary part to be concerned with before doing any research on this issue; otherwise inefficient estimation might be the probable outcome of any study. In most developing countries like India, studies of waste generation, that consider the issue of various MSW sources, are not available because of the scarcity of technical knowledge and funding. The existence of different classification of MSW creates confusion and makes it difficult to interpret and compare the results of generation analysis (Buenrostro *et. al.*, 2001).

In this study, municipal solid waste is conceptualised as the solid waste generated within the territorial limits of a municipality, independently of its source of generation. With this assumption and based on the economic activity that generates a solid waste, source classification can be categorised into three divisions (urban, industrial and rural); and seven classes of sources: residential, commercial, institutional, construction/ demolition, agricultural - animal husbandry, industrial and special (the waste which needs special techniques for control, either because of relatively hazardous, because of its condition or state, or because control is enforced by the standing environmental regulations. This waste is generated in the sectors such as scientific research, health, industrial and automobile maintenance shops, human and veterinarian drug stores, airport and terrestrial transportation terminals among others). When applied at different geographical scales, this classification enables the assessment of the volume of MSW generated, and provides an overview of the types of residues expected to be generated in a municipality, region or state. In the next section, we will discuss about the trends and pattern of waste generation of an area and how this is related with economic activity and population level.

B. Trends and Pattern in Waste Generation:

It is quite obvious that waste generation depends largely on population level along with income standard. Place with high population figure likely to generate more wastes though the characteristics of wastes can vary from place to place depending on the socio-economic, cultural and environmental standards (Venkateswaran, 1994). This resembles with the sample study done by Abu Qdsais *et. al.* (1997), where they derived that waste generation rate depends on the level of income, with an increase of about 35 percent for the high income level residents over the average rate. Similarly, high-income country i.e. with more economic activity generates more waste than its small income counterpart. Various forms of model associated with estimation of quantity of waste generated can be applicable for testing empirical findings. In one of the form, waste forecasting is based on economic activities and time (Karavezyris, 2000). The explanatory variable may be overall consumption, inputs or outputs of production. The model ideally applied can be described as follows:

$$\log W_i^t = \alpha + \beta \log Y_i^t + \gamma t$$

where W_i^t is the amount of given waste of category i at time t, Y_i^t is the t^{th} period amount of a specific economic activity expressed in monetary or physical terms, β stands for a constant ratio of the generated waste to the output of the relevant economic activity, and γ stands for a dynamic ratio of generated waste to the output of the relevant economic activity and α as the associate constant term. Owing to lack of reliable data and significant margins of error in estimates due to variations in data quality and availability, the generic model can be reduced to a most simplistic approximation as under:

$$W_i^t = \kappa Y_i^t$$

where κ is the waste coefficient of base year.

In case of municipal/regional planning estimation of further quantities and composition of household wastes are derived as a function of population level also. The model can be interpreted as follows: $W_i^t = \lambda P_i^t$

where λ is a constant term and P stands for population. Frequently, municipal waste which is generated from industrial places may be estimated as the function of the employees in the various industrial branches. The basic estimates of total quantities are called base line projection and are modified by using reduction quotas (Chakrabarti, 2003).

Beede and Bloom (1995) have used time series data for 36 countries on per capita municipal solid waste generation to estimate income and population elasticity of MSW generation following the relation given below:

$$\log(\text{annual MSW generated by weight}) = \alpha + \beta_0 \log(\text{per capita GDP}) + \beta_1 \log(\text{population}) + \varepsilon$$

where α: Constant term

β_0: Income elasticity of MSW generation

β_1: Population elasticity of MSW generation

ε: Associated error term

Their estimates indicate that MSW is responsive to both income and population but more responsive to population than to income (i.e. β_1 is extremely close to 1 and β_0 is significantly less than 1). To construct an estimate of global MSW generation Beede and Bloom (1995) used the cross-country data for 149 countries in 1990 and estimated regression coefficients. They found that the global generation of MSW to be of the order 1.3 billion tones which was more than the combined output of wheat and rice in that year. The estimate of MSW for different country groups have been given in the Table 2.1.

It can be seen from the Table 2.1 that the economy with higher income accounts for a disproportionate share of MSW generation with respect to the population, while developing countries account for a disproportionate share of MSW generation on the basis of income. But here the interesting fact is that per capita per day waste generation is almost double in high-income countries than the world average that clearly reflects the direct relationship between economic activity and waste generation. The disproportionate share of MSW generation with respect to population can be rationalise by the information that number of high income countries is too less compare to the number of other countries; so volume of waste generation does not vary directly with total population on the

aggregate level, but this direct relation exists for the case of a particular country.

Table 2.1: MSW Generation for Different Groups of Countries

Income group	Total MSW generation		Population size		Percentage of world total GDP	Kilograms of MSW per capita per day
	Billions of metric tons a year	Percentage of world total	Millions of people	Percentage of world total		
Low	0.598	46.3	3091	58.5	18.7	0.53
Lower-Middle	0.145	11.2	629	11.9	9.9	0.63
Upper-Middle	0.193	14.9	748	14.2	16.5	0.71
High	0.357	27.6	816	15.4	54.9	1.20
All Economies	**1.293**	**100.0**	**5284**	**100.0**	**100.0**	**0.67**

Source: Beede and Bloom (1995)

Within a country waste generation rate also differ between urban and rural areas. It can be assumed that rural population generates less waste because of lower per capita income that leads to lower per capita consumption.

In a most recent study Dyson and Chang (2004) presented a new approach - system dynamics modeling - for the prediction of solid waste generation in a fast growing urban area based on a set of limited samples. In reply to the traditional statistical forecasting models, such as the geometry average method, saturation curve method, least square regression method and the curve extension method, which basically are expressions of cause-effect or illustrations of trend extension in order to verify the inherent systematic features that are recognised as related to the observed database; they used the fuzzy forecasting and grey dynamic modeling as a promising approach for handling forecasting issues under uncertainty. They have chosen, for their case study, the city of San Antonio, Texas (USA) as the area is becoming one of the fastest growing regions in North America due to the economic impact of the North American Free Trade Agreement (NAFTA). On the basis of the data for only 3 years viz. 1980, 1990 and 2000, they have projected the amount of waste generation for the year 2010

by presenting various trends of solid waste generation associated with five different solid waste generation models (with driving factors such as total income per service center, people per household, historical amount generated, income per household and population) using a system dynamics simulation tool - Stella. Their technique is extremely helpful for the cases where data availability is to small. This new method of projecting future values has gained importance in international arena and is largely used in various fields where insufficiency of data affects the viability of traditional forecasting methods. Next section will give us the idea about options and policies for waste management.

C. Options and Policies for Waste Management:

Other than any environmental and/or health risky options like land filling, incineration, composting etc. there can be three ways of managing waste viz. waste minimisation (or, source reduction), recycling and reuse. Of these the last two can be clubbed together as recycling is done with the intention of reusing the product. Environmentalists advocate for waste minimisation, as the most preferred option of waste management, followed by recycling/ reuse and the later, according to them, should take priority over land filling. And this hierarchical ordering may be judged from the point of view of non-availability of suitable land for landfill as a result of growing ecological and environmental concern among the people and misuse of economically recyclable resources (Bowers 1997). But from the economic perspective policy measures based on waste hierarchy must be accepted only after considering relative cost-benefit analysis of those options (Morris-Holthausen 1994; Turner, 1995). But in reality this environmental sequence is rare to observe. Particularly in most developing countries, a large quantity of waste is dumped in an uncontrolled manner or burned in open air, which should not be the most preferred option. Here it is to be noted that environmental impact varies from materials to materials; so is the ranking of waste managing options.

Given the external costs associated with other options such as land filling, composting, incineration, etc. reduction of waste by reuse or recycling of it appear to be eco-friendly but they are of course not mutually exclusive and the optimum solution may be some combination of reduction in waste creation and

the recycling of what remains. However, source reduction is difficult to achieve on a large scale at the local level and if the problem is seen primarily as that of the waste of raw materials then recycling is preferred as the only alternative. Recycling attributes many benefits to waste management such as reducing the need for disposal capacity, lowering emission from landfill and incinerators and reducing litter and improper disposal. It also reduces energy use and related emission in production units and also use of virgin materials.

Interestingly, these have an implicit indication towards different sources and form of market failure. The imperative, therefore, is to introduce economic instruments like tax and subsidies which would internalise disposal costs, making recycling of waste and the use of secondary raw materials comparatively more attractive.

D. Economic Instruments for Managing Municipal Solid Waste:

Though decreasing disposal may reduce costs for the community as a whole, individual households lack a financial incentive to decrease the amount of waste that they generate. That is why it became necessary to introduce economic instruments in various forms to mitigate the difference between private and social marginal costs, which is the basic characteristic of any public good.

When households pay a flat fee, they usually do not consider disposal costs in their purchasing and recycling decisions. So producers lack adequate incentive to produce the goods that are less costly to dispose off or use recycled materials in their production process (Dinan 1993). So, from economics perspective, it is always better to introduce per unit tax of garbage generation to internalise the volume based cost.

Unit Pricing for Garbage Collection:

The most direct way to internalise the external costs of garbage disposal is to tax each bag of garbage. In most developing countries and even in some developed countries there exists fixed price collection service regardless of the volume of waste. Dinan (1993) points out that such system leads to increase in disposal of waste in two ways; (i) since household does not face any extra charge for the additional unit of garbage he dumps, he lacks a financial incentive to

consider disposal cost in his purchasing and recycling decisions. (ii) This in turn, does not provide producers any incentive to produce the goods that are less costly to dispose of. Strathman *et. al.* (1995) strongly argued, by deriving the efficiency losses through estimating the elasticity of demand for landfill disposal of municipal solid waste using data from Portland, Oregon metropolitan area, that municipal financing of solid waste services from general tax revenue causes efficiency losses and communities should opt for volume or weight-based pricing of garbage to get higher benefit. Fullerton and Kinnaman (1996) analysed the effect of volume based pricing program in Charlottesville, Virginia, United States, in which household waste was charged per bag. It was found that the program had a substantial effect no volume but little effect on the weight of the waste - the weight per bag increased considerably. Moreover, the weight of recyclable materials also increased.

Hong, Adams & Love (1993) analysed solid waste generation and recycling behavior of the households within a household production framework. They have founded that marginal pricing system with zero charges for recyclable is expected to provide incentives for household to disposed of less waste through garbage collection services (by generating less total waste and/or by increasing recycling effort).

However marginal cost pricing of garbage may be effective as long as household reduce the amount of waste generated and increase recycling. Fullerton & Kinnaman (2000) demonstrated that if household wastes are constrained by two disposal options i.e. garbage disposal at landfill and recycling then, marginal cost pricing would tend to substitute recycling for garbage disposal. But if illegal disposal or burning features as a third alternative in the household's disposal choice set, then unit pricing would encourage illicit burning (Fullerton and Kinnaman, 1995).

Compare to flat fee unit pricing is obviously much better as the fee is applied according to the volume of the garbage. But there are two major criticisms of this policy; one, under unit-based pricing households are charged same price for each unit of trash regardless of the content. However, all types of trash do not impose same disposal costs. For example, a bag full of old tires or old batteries is more costly to dispose of than a bag full of papers. And the second is

unit-based pricing provokes individual to be engaged in illegal disposal (e.g. burning waste, dumping it in vacant lands or in private dumpsters) (Dinan 1993; Fullerton-Kinnaman, 1995).

Moreover, administrative price of implementing the program may exceed the social benefits. Fullerton & Kinnaman (1996) estimated the cost for Charlottesville, Virginia and found that social benefits from marginal cost pricing get reduced significantly in presence of illegal disposal option. According to Dinan (1993), a uniform tax on all types of garbage might be inefficient if materials within the waste stream produce different social costs. But differentiated tax formulation would amplify administrative costs.

In a situation where illicit dumping is plausible and impossible and/or costly to be charged Fullerton-Kinnaman (1995) showed that optimal policy is a kind of deposit refund system. In such cases legal disposal should be subsidised and since this tends to generate income effects, consumption should be taxed. Dobbs (1991) also showed that if external cost of litter and garbage exceeds the external cost of legally disposed garbage, and then the optimal tax on legally disposed garbage could be negative.

Virgin Material Taxes and Subsidies:

In view of the above-mentioned problems associated with unit pricing of waste generation, economists advocate the implementation of a tax on virgin materials (or reuse subsidy on the other way) to achieve an efficient allocation of resources in a scenario where garbage disposal produces external costs. It has been justified on the ground that primary inputs enjoy effective subsidies compared to secondary inputs and these have an unfair comparative advantage over their recycled counter part. Dinan (1993) admits that virgin material fees can increase the demand for recycled materials and hence reduce disposal requirements. In addition, they can also raise prices for recycled materials that might be welcomed by benefited people. But an efficient level of waste disposal can be obtained by combining a tax on producers of goods that may ultimately be disposed of and subsidy for end users of recycled materials.

In Fullerton and Kinnaman (2000) study, virgin materials in fact, would earn subsidy on account of the fact that (a) income earned by the producer is taxed

at the rate of capital gain instead of the corporate income tax rate; (b) mineral exploration is traditionally encouraged on public lands; and (c) freight rates charged for the recycled materials are often higher than their virgin material counterpart

Virgin material taxes used in isolation can either lead to inefficient reductions in production of valuable consumer products or actual increases in municipal solid waste disposal (Dinan, 1993). Such taxes must be combined with taxes on output and other inputs to production in order to generate optimal amount of solid waste disposal (Palmer and Walls, 1994; Fullerton and Kinnaman, 1995).

Tax on virgin materials has often been criticised on the basis that it works for specific industries but would fail as general policy instruments because virgin and subsidised recycled materials are not always treated as substitutes and recycling is influenced by other factors like supply side bottlenecks other than state incentives so that implementation or removal of state subsidies is unlikely to affect the rate of recycling. Usage of recycle inputs requires new capital stocks that are highly expensive. As most of the existing technologies are suitable for the use of virgin materials in production, the short run marginal cost of using substitute input is high. Anderson and Spiegelman (1977) found that the price elasticity of demand for scrap steel and old newspaper is inelastic. Firm's reluctance for investing capital to allow for the use of recycled input may be due to the uncertainty over obtaining a steady supply of recycled input.

Palmer and Walls (1994) demonstrate that while a tax on primary materials would bring about an efficient mix of inputs it can discourage production and consumption. They argue that virgin material tax must be supplemented with a subsidy on final goods. In fact Dinan (1993) speaks of achieving the social optimum by replacing virgin material taxes by a combination of disposal tax and reuse subsidy. Fullerton and Kinnaman (1995) show that a tax on virgin material would not help to correct the externality associated with garbage disposal; rather it is only necessary to reduce the external costs of extracting the virgin materials.

Advance Disposal Fee:

Advance disposal fee (ADF) is a tax on goods levied at the time of sale, based on the cost of ultimate disposal of goods. The rationale behind such fee is that when goods are exchanged, the externalities from disposal of these goods are not reflected in the product price. Collecting the disposal costs in advance would certainly raise the product prices to reflect the true cost to the society leading to reduce consumption of goods that are waste generating in nature. In fact Calcott and Walls (2000) have developed a theoretical model to show the appropriateness of ADF as an optimal policy only for non-recyclable items. For recyclable items, they have suggested a deposit-refund system as the most advocated policy in the waste management literature.

Deposit Refund System:

A deposit refund system is a two-part instrument where the deposit is set equal to the social marginal cost of disposing of the materials and the optimal refund is set equal to the difference between the marginal external cost of garbage and the marginal external cost recycling. If the external cost is zero then the refund matches with the deposit as in the case of glass, bottles and aluminum cans. Several economic studies have favored the use of deposit refund system including Dinan (1993), Dobbs (1991), Fullerton & Kinnaman (1995), Palmer and walls (1994), Palmer *et. al.* (1997), Fullerton and Wu (1998) etc.

Palmer, Sigman and Walls (1997) made a comparative study on the impact of three policy instruments ADF, recycling subsidy and deposit refund system on overall waste reduction. While the first two appeared to be cost inefficient, Palmer et al considered deposit refund system to be most efficient. In their partial equilibrium model, a $45 per ton deposit refund would reduce all the waste by 10 percent, where as to bring about a comparable reduction either an ADF of $85 per ton or a recycling subsidy of $98 per ton was required. To explain why deposit refund is the preferred alternative, Palmer et al (1997) pointed out that deposit refund gives rise to both source reduction and recycling whereas the other two policies take advantage of either only source reduction or only recycling as opportunities for disposal reduction. The ADF discourages

consumption, thus decreases the amount of material available for the recycling leading to the reduction in recycling. On the other hand, recycling subsidy encourages recycling but by lowering the effective price (which in this model is market price loess the scrap value of the goods) of the final material for recyclers though it encourages consumption. Hence post consumption waste increases. As the ADF fails to take advantage of opportunities for recycling and the recycling subsidy fails to take advantage the opportunities for source reduction, these policies should be implemented properly to achieve a significant level of waste reduction. However due to high administrative cost the ADF might appear to be most attractive (Palmer *et. al.* 1997). Atri and Schellberg (1995) suggest that deposit could be levied either on the production or sale of the goods. If the refund is given to the households then the increase in supply of materials will drive down the price of recycled materials to the firms. If the firms receive the refund they will increase the demand for recycled materials and drive up the price received by the households. But in the presence of high transaction cost, the form of deposit refund may alter. In a world of imperfect information and high transaction cost the deposits and refunds should be imposed on manufacturers rather than on the consumers. Here the manufacturer pays a deposit and the recycling facility is paid a subsidy when it sells recycled input to the manufacturer. These operations, however, need not make any payment to the consumer.

Again Fullerton and Wolverton (2000), remark that the deposit rate may not match with the rate of refund, as they may not apply to the same commodity. The deposit is the normal excise tax on output, which may be paid by the seller or by consumer. The refund or the subsidy system may be applied to the recycling and sanitary landfill, so that it could be paid either to the households or to the waste processing firms. In competitive equilibrium for the recycling firm to receive more subsidies, it would be willing to offer inducements to consumers such as free collection of recyclable wastes as individuals would not feel the urge to stand in queue to get the refund amount (Fullerton and Wolverton, 2000).

Fullerton and Kinnaman (1995) discuss a situation where they introduced the possibility of illegal dumping. They showed that if the first best outcome, i.e.

a Pigovian tax on illegal dumping, is difficult to attain; a deposit refund system would achieve the social optimum. To do this, the deposit must take the form of consumption tax (or income tax) and the refund appears as a subsidy to recycling.

In addition, Fullerton and Wu (1998) showed that the efficient solution can be obtained either by a 'downstream' tax on waste disposal or by an equivalent 'upstream' tax on production process that gives rise to subsequent waste.

However, the deposit refund system may have some operational problem as well. Bowers (1997), for instance, warns that deposit refund system can only work for suitable reusable containers such as glass bottles and only for products that cannot be sold in such containers. One single policy cannot be applicable to all products. The overall impact of the policy depends on how much the recycling sector is organised and how effective is the policy for recycling (Zoboli 1994). The system may generate a surplus of recyclable material if the recycling capacity is not adequate. When the deposit takes the form of a tax on output and refund a subsidy to recycling on sanitary landfill, few other problems could arise. Firstly, if the subsidy is high enough it might induce some individuals to steal waste from others in order to obtain subsidy.

Thus it may work best where the subsidy is implicit, such as the free collection of curbside garbage recycling. Finally, if the economy is open, deposit would have to be collected on imports and the refund may not be received on exports.

Recycling Subsidy:

Recycling subsidy is a refund to the consumers if they bring the product after their use for recycling otherwise they would not get any such refund. The amount is based on the cost of ultimate disposal of goods. Recycling subsidy would necessarily lower the effective price of the product to the consumers and give the incentive to recycle more. But, on the other hand, it increases the level of consumption and thus the amount of waste. Moreover, it is very difficult for the consumer to collect the subsidy always after using the product and this method is not applicable for the non-recyclable items.

E. Command and Control:

The Command and Control (CAC) instruments are in the form of fines, penalties and threats of legal action for the closure of the polluting factories and imprisonment of the owners. These can be applied either for facilitating the specific technology for environmental management or for the realisation of the specific environmental standards (Murty, 2001). An important distinction between CAC instruments and economic instruments is that in the former the marginal cost of non compliance is infinity while in the latter the marginal cost of non compliance is finite.

One CAC instrument used in case of solid waste management is that of recycled content standard: a law requiring firms to employ a specified minimum portion of recycled materials in their product. But recycled content standard has problems similar to the virgin material tax. The problem with this option is that the standard can lead to either too much or too little output or solid waste, depending on the form of production function; it also lead to inefficient use of other factors of production such as labor. Palmer and Walls (1997) argued that given the information of firms' production function of Cobb-Douglas type, optimal product tax and tax on other inputs to production must be used in combination with the recycled content standard. But information required for implementing this combination of policies is, generally, beyond the reach of policy makers. Moreover, in presence of heterogeneous firms, setting the optimal policy is almost impossible because on one hand, firms can easily misrepresent their production function with an incentive to reduce output and labor taxes and the recycled content standard they face and on the other hand, firms can use multiple recyclables to produce a single output or produce multiple outputs with a single recyclable or export the recyclables. According to them deposit refund system is the alternative policy that can overcomes many of the pitfalls of recycled content standards and other input directed policies.

Given the mitigated success of the traditional CAC approach, there can be another option of negotiation between industrial circles, the government and the local authorities regarding use of recycled materials, waste reduction, etc. through appropriate legislations and financial incentives.

What we have already told that use of economic instruments is not at all a common practice in any developing countries like India. Here no such weight based or volume based charge for generating waste has been applied, rather to some extent, the practice of source separation is noticeable in some places mainly through the initiatives taken by the local authority with peoples' participation. In the next chapter we will discuss about the municipal solid waste management scenario for India as a whole and apart from that the experiences of developing countries will also be talked about along with some special reference of advanced countries where possible.

CHAPTER III

Management of Municipal Solid Waste in Developing Countries

Introduction:

Since pattern of waste generation varies from country to country, even within a country from place to place, mainly due to change in geographical, environmental, socio-economic and cultural factors; waste generated in developed countries are different in terms of physical as well as of chemical characteristics than that of in developing countries. India, being a developing country, holds all the characteristics of end use of third world nations. Here, the main component of waste is organic matter that makes high moisture content in it. The reason behind that is, till date, people here mainly use vegetables and related organic matter in their daily consumption basket and they are far off using packaged foods as like the people in advanced countries. But exceptions are there in few modern cities like Delhi, Bangalore, Mumbai, Kolkata, etc. where people, due to the effect stemming from globalisation, have started using more packaged goods than earlier. Apart from those cities, the rest of India is still broadly like a prototype of underdeveloped countries. The amount of waste generation, considering the total amount, is not at all proportional to any other big countries. Moreover, per capita waste generation is somewhere around one third to one fifth of per capita waste generation in advanced countries. In spite of that, the municipal solid waste management in India is in vulnerable condition due to the organisational loopholes, administrative legacy along with drastic change in consumption pattern of the urban people as a result of globalisation as well as of consumerism. Along with that, population pressure adds some extra burden to this problem. Moreover, cost incurred by the municipal authorities for municipal services varies from country to country. It has been observed that in advanced countries these costs are much higher than that of in developing countries. In crux, the municipal services provided in the developing countries suffer from various demerits such as social unawareness, administrative loopholes, paucity of funds, and lack of pragmatic view among the policy makers.

So to capture all these issues we have designed this chapter in the following manner: section A talks about the trend of population of India over the last century. The overall scenario of municipal solid waste management in India is discussed in section B. Section C will describe the story of some other developing countries with special reference to the performance of developed countries, where possible. Let us discuss the story of municipal solid waste management in Indian context.

A. Population Trend in India:

Throughout over the last century, India has been consistently experiencing an increasing trend of population and currently India ranks in the second position in terms of having maximum population after China. According to the Census of India, 2001, at about 27.8 percent (28.5 billion) of the total population of the country (102.8 billion) lives in urban areas. The decadal growth rate of the population has been above 30 percent during the period 1991-2001. The alarming part here is that, according to experts' view; India will become the most populated country by the year 2051. Moreover, TERI estimates indicate that in 2047, India's urban population will grow to 79.6 billion, which would be around 50 percent of the total population (TERI, 2001). The increasing trend of overall population along with the growth rate can easily be understood from the Table 4.3:

Table 3.1: Population Trend in India over the Last Century

Year	1901	1911	1921	1931	1941	1951	1961	1971	1981	1991	2001
Population	23.8	25.2	25.1	27.9	31.8	36.1	43.9	54.8	68.3	84.6	102.8
Growth (%)		5.75	-0.31	11.0	14.2	13.3	21.5	24.8	24.6	23.8	30
Urban Population						6.24	7.89	10.9	15.9	21.7	28.5

Population figures are in billion.
Source: Census of India, various issues.

With a population growth rate around 30 percent and along with a rapid increase in the urban population, the country generates a significant amount of

solid waste, managing which, nowadays becomes a critical matter of concern. Moreover, most of the cities and towns fall far short of managing MSW because of various technical drawbacks and administrative legacy. The overall situation of municipal solid waste management is, therefore, an important area of interest to the experts.

B. Municipal Solid Waste Management in India:

The municipal bodies in India are entrusted under law with the obligatory functions of conservancy or public cleaning and scavenging work. The term 'solid waste management' connotes a total system covering all processes from the collection to the disposal stage for all types of refuse. The Gujarat Municipal Act, 1963, for instance, lays down that it shall be the duty of every municipality to make reasonable and adequate provision for "cleaning public streets, place and sewerage, and all places not being private property, which are open to the enjoyment of the public". Statuses in other states of the country have identical position. These provisions do not at all mean that other agencies have no role in the collection and disposal of wastes. In several places, the public sector undertakings and large industrial houses make their own arrangements for waste collection and disposal, and in some cases, undertake some kinds of primary treatment. But, as a whole, services regarding MSW are mainly performed by the government bodies. In case of India, the component wise discussion of MSW deserves extra weight, as the country is full of diversity in many respects.

Generation:

Solid waste generally consists of dry refuse such as ashes, dust, food wastes, packaging in the form of paper, metals, plastics or glasses, kitchen wastes, discarded clothing and furnishing, garden wastes, and so on. In advanced countries, solid waste may also contain heavy articles like unused cars, televisions, refrigerators, other electronics goods, etc.

Over the years India has been experiencing a gradual increasing trend in waste generation causing from a burgeoning rate of population. At the time of independence, total waste generation was only 6 million tons, whereas it

reached to 48 million tons in the year 1997 (TERI, 1998). But according to the data given by Toxics Link, annual municipal solid waste generation in India is about 36.5 million tons with per day generation of 0.1 million tons. On an average, more that 25 percent of the municipal solid waste is not collected at all; 70 percent of Indian cities lack adequate capacity to transport it (Toxics Link, 2005). The per capita waste generation varies between 0.2 kg per day to 0.6 kg per day and the current municipal solid waste generation is estimated to be approximately 0.5 kg per capita per day (Tenth Five Year Plan, 2002-07). The rate of waste generation also varies among different income groups. The variation in per capita waste generation between lower and higher income groups ranges between 180 to 800 grams per day (Toxics Link, 2005). It is very evident from the above mentioned data of different sources that in India, due to the lack of initiatives in maintaining records regarding waste collection and its treatment, there is no way of estimating the actual figure of those variables for the country as a whole. Thus estimation based on sample values differs significantly from source to source. Concerning authorities of different cities keep some records pertaining to MSW management of some particular years that are not updated regularly. Though there are some exceptions like Delhi, where the concerning authority keeps month wise figure of total municipal solid waste collected. Table 3.2 shows an overall increasing trend of waste generation in India over the years.

Table 3.2: Generation of Waste over the Years

Year	1947	1951	1961	1971	1981	1991	1997
Daily Per Capita Generation (gm)	295	305	340	375	430	460	490
Total Waste Generation (MT)	6	7	10	15	25	37	48

MT: Million Ton, gm: gram
Source: TERI (1998)

Moreover, apart from the total waste generation trend, the composition of Indian municipal solid waste is also quite different from that of other developed countries like US, European countries, etc. The nature of India's solid waste matches with that of other developing countries in terms of containing high organic matter having significant proportion of moisture and comparatively low

recyclable products like paper, plastics, etc. The second largest component in MSW is earth, sand and grit, which are caused mainly due to unpaved road, lack of neatness among the people and shortage of waste collection activity. The physical composition of Indian municipal solid waste is shown in the Table 3.3.

Table 3.3: Physical Composition of MSW in India

Composition	Percentage
Biodegradable	52
Metal scrap, rubber, textiles, leather, etc.	11
Stones and rubble	8
Fine earth and sand	23
Plastics	1
Paper and paper products	5

Source: Fact Sheet, Toxics Link, Number 15, March 2002.

There are two main components of Indian urban waste namely biodegradable and non-biodegradable. Biodegradable components include fruits, vegetables, meat, plant waste, food waste, wood etc., whereas non-biodegradable components consisting of recyclable waste like plastics, paper, leather, glass, fabric, rubber, battery, metal etc. Due to these characteristics, calorific value of Indian solid waste is between 600-800 Kcal/kg and the density of waste is between 330-560 Kg/m^3 (Toxics Link, 2005).

Table 3.4: City-wise Composition of Municipal Solid Waste

Cities	Paper	Plastic	Metal	Glass	Ash & Earth	Total Compostable
Calcutta	3.18	0.65	0.66	0.38	34.00	47.00
Delhi	6.29	0.85	1.21	0.57	36.00	35.00
Nagpur	1.88	1.35	1.33	1.34	41.42	34.81
Bangalore	4.00	2.00	-	1.00	15.00	78.00
Bombay	10.00	2.00	3.6	0.2	44.20	40.00

Figures are all in percentage.

Source: Background information for Conference of Mayors and Municipal Commissioners, Urban & Industrial Energy Group, Min. of Non- Conventional Energy Sources, New Delhi, 1996.

The interesting thing is that, the proportion of the recyclable components like paper, plastics, etc. are very small compare to other components. But this is true for the country India as a whole. Considering any particular city of Table 3.4, which can be characterised as modern one, we can notice that proportion of paper and plastic is much higher in that city compare to national average. Upcoming cities like Bombay, Delhi show a greater proportion of paper as a waste that represents the trend of these cities towards adopting packaged goods. In major cities, proportion of paper and plastic in the total waste is much higher than the national average.

Collection:

Conservancy activity is usually entrusted to the health department in a municipality in almost all cities and towns in India. This is mainly because of the association of sanitation and public hygiene with Public Health. The transport of waste is done by mechanised and non-mechanised modes from collection point to the disposal sites. For street sweeping, collection of refuse and for loading and unloading the refuse from the vehicles, the municipal bodies employ a large number of conservancy staffs, who are provided necessary instruments in which they are required to deposit the end use.Given the high organic content in waste and the nature of tropical climate, managing municipal solid waste is an important service to do for the society otherwise, uncollected and indisposed waste can result in various types of diseases and serious health risks. Therefore, frequent collection and disposal is absolutely essential.

The question that arises is: who is responsible for the removal of refuse and waste from the houses and commercial premises? The answer to this, according to the Acts, varies from state to state. In the Gujarat municipalities Act, no specific mention has been made in respect of this question except that the municipal councils shall make provision for cleaning of public streets and places. The Madhya Pradesh Act vests this responsibility upon households who, according to the provisions, are required to deposit the refuse and other offensive matters in public dustbins. In the local bodies of Tamil Nadu, the Municipal Councils undertake door-to-door collection of waste.

In actual practice, in smaller and medium sized urban centres, all households and commercial establishments throw the refuse and offensive matter on the streets, from where it is collected by the municipal bodies. In larger local bodies, where door-to-door collection by municipal agencies is not practiced, the households enter into private arrangement with the sweepers to get the refuse and offensive matter collected from the houses and deposited in the dustbins. The garbage stored in the bins is loaded by the conservancy staff on to bullock carts (mainly in smaller towns), or trucks, which call at least once a day near each collection point. In certain cases, garbage is transferred from the bins located in the narrow streets by the civic staff in larger barrows to the main streets for further transportation. In market areas, slaughterhouses and public places, the municipal sweepers collect the garbage and store it in a large bin to be transported away.

The real picture is far from the hypothetical one. Generally around 70 percent (Range: 69-83 percent) of generated wastes have been collected by the municipal authorities and the rest is usually lying along the roadside, creating pollution in various forms. Table 3.5 shows the range of refuse generation and disposal along with the percentage of endues that are disposed as proportion of generation. Though in recent years the average amount of refuse generation has increased with the increase in population but the average percentage of waste disposal, as proportion of generation remain more or less stagnant. The main reason behind that is the number of cities that are short of municipal workers has increased over the years (Bhide-Sundaresan, 1984).

Table 3.5: Collection Performance of Municipal Services in India

Components	Range (grams/capita/day)	Average
Refuse Generation	294-484	378
Refuse Disposal	203-354	274
Disposal / Generation (in %)	69-83	72.5

Source: NIUA, Management of Urban Services, 1986;
NIUA, Upgrading Municipal Services, Norms and Financial Implications, 1989.

A relatively recent figure (Table 3.6) that consider the per capita waste generation and collection for 7 Indian cities, shows that for some cities the scenario has been improved in terms of collection efficiency, though it is still in a bad state for others.

Table 3.6: City-wise Collection Performance of Municipal Services

City	Waste Generation Per Person*	Waste Collection Per Person*	Collection Efficiency (%)
Surat	458	435	98.00
Chennai	591	578	80.87
Bangalore	554	444	80.14
Ahmedabad	518	409	78.95
Mumbai	596	469	78.69
Pune	580	353	73.54
Baroda	463	259	55.93

* In Grams per Day.
Source: Mohapatra, 2001.

From the above table it is very clear that the city Surat is performing best among others in terms of collection efficiency and the performance of other cities are not that much satisfactory. On an average the collection efficiency of solid waste in Indian cities ranges from 50 percent to 90 percent (Toxics Link, 2005).

Transportation:

Solid waste is usually transported in open trucks, compaction vehicles, tractor-tailors, power tillers, tricycles or carrier containers. However, open trucks are used by most of the municipal corporations; in small towns, even bullock carts are employed for the purpose (TERI, 1998). The principal reason for using bullock carts or tricycles is their easy availability and mobility in narrow lanes and lack of financial resources to invest in and maintain modern vehicles and equipments. The vehicles are normally owned by municipal authorities. Lately, however, a few corporations have resorted to hiring vehicles from private contractors. Hired vehicle have been found to work more effectively

and efficiently if monitored ad held accountable for the services rendered by them. The concept is catchy because it is cost effective. On an average, a cubic metre of MSW at the generation site weighs about 500 kg (Bhide and Sundaresan, 1983). Considering the daily per capita generation rate of 480 grams, the volume of waste required to be transported is about 960 cubic metres per million populations. Assuming that a truck makes three trips in a day, the minimum transport capacity required is about 320 cubic metres per million populations every day (TERI, 1998).

The Table 3.7 shows the available transport capacity of 44 Indian cities, where about 70 percent of them do not have such capacity. The figure might be even higher, considering that the fleet in most cities is old and its performance is very poor.

Table 3.7: Transport Capacity to Carry Municipal Solid Waste

Capacity (Cubic Metres / Million Population)	Cities (%) (44 cities)
<100	4.5
100-200	34.1
200-300	29.6
300-400	25.0
>400	6.8

Source: Bhoyar and others (1996) in TERI, 1998.

The uncollected waste is normally finds its way into sewers; some of it is eaten by cattle; and some lies about for a few days before sweepers collect it together and burn it in the open air. This is mainly because small transport vehicles generally do not synchronise with bulk waste storage. That is why multiple handling of waste becomes necessary and thus making the entire operation unhygienic and expensive.

In many cities, despite inadequate fleets and funds, vehicles are used in only one shift municipal trucks are thus grossly under-utilised. Often the trucks or vehicles are not fully loaded by the workforce, resulting in loss of productivity or manpower and equipments.

Disposal:

The refuse collected from various points is disposed off by various methods in different urban centres, viz., dumping, sanitary landfill and composting. Majority of smaller municipal authorities adopt dumping due to non-availability of mechanised forms of transport. Generally, the low lying areas and the outskirts of the towns are used for this purpose. However, they constitute a health hazard and become breeding grounds for flies and mosquitoes. Only a few cities follow such good practices as organised tipping of wastes, and covering the top layer with earth before compacting it further. Sanitary landfill is properly practiced only in large cities. In some places, dumping is done illegally on private property of farmer. Out of the total municipal waste collected, on an average, 94 percent is dumped on land and 5 percent is composted. The performance regarding treating the waste can be overviewed for some of the major cities of India from the Table 3.8.

According to a report of ESCAP (The Hindustan Times, New Delhi, Nov. 12, 1993) on 'State of Urbanisation in Asia and Pacific', most of the waste in Asian cities is disposed off in landfills, which are generally open dumps rather than proper sanitary landfills. The report identified two main determinants of environmental degradation in developing countries, namely economic factors and institutional inadequacies.

Economically, because of the inability of most planners to value natural resources in monetary terms, the cheapest, the least efficient, and the dirtiest production process has been favoured. This fact can be defended by the information that the urban local bodies spend approximately Rs.500 to Rs.1500 per ton of solid waste for collection, transportation, treatment and disposal. Out of this amount, about 60-70 percent is spent on collection, 20-30 percent on transportation and only a meager 5 percent is spent on final disposal (Toxics Link, 2005). It is said that, the natural water sources such as rivers get increasingly polluted by sewage, industrial effluent and solid wastes. In many Asian cities, untreated household and industrial wastes are dumped directly into lakes and rivers, often contaminating the drinking water through leachate and spreading diseases (Mathur, 1994).

Table 3.8: City-wise Waste Disposal Performance

City	Solid Waste Collection*	Treatment*	Mode of Disposal (%)		
			Dumping	Composting	Others
Ahmedabad	1683	84	95	5	.
Bangalore	2000	200	90	10	.
Chennai	3124	.	100	.	.
Delhi	4000	300	93	7.5	.
Hyderabad	1566	100	94	6	.
Kolkata	3692	.	100	.	.
Mumbai	5355	500	91	9	.
Pune	700	50	93	.	7
Surat	900	225	75	25	.

*In Tons Per Day
Source: CPCB, 1999.

As an alternative method of disposing waste, composting has been expressed as useful and eco-friendly option by the government for several years. For preparing compost from refuse both manual and mechanised methods are being used. However, the manual process is more prevalent because of low cost and less skilled manpower. Mechanisation in composting has only been introduced in a few big cities with the objective of speeding up the process of aeration and bacterial breakdown of materials and production of quality compost. But, in most of the cities local bodies just dump garbage into a pit or trench, partly cover it, keep it for six months and sell it out in "as is where is" condition at a throw-away price. The entire operation is unhygienic, unscientific, foul smelling and very slow. In some cities where microbial composting of waste or vermi-composting is being done with private sector participation, good results are seen. Assistance from the government in the form of capital subsidy and grants are also available for infrastructural items to enable the construction of mechanical compost plants and the conveyance of adequate solid waste. This type of plants have been constructed in some of the cities like Ahmedabad, Baroda, Bombay, Bangalore, Calcutta, Delhi, Jaypur and Kanpur; however, many of them have been closed due to a variety of reasons including high cost of production, lack of demand, inability to sell compost at the economic price, etc.

Moreover, the life span of the existing disposal sites in the cities varies between one to ten years depending upon the size of the landfill. In almost all the cities, finding of a suitable disposal site is a major problem faced by the municipal corporations/ municipalities. They face stiff resistance from the public in locating dumping sites in their neighborhood. The difficulties in locating large area of land for dumping are forcing the authorities to go in for recycling and other modes of disposal. Private entrepreneurs are being encouraged to start projects in microbial composting, pelletisation or vermi-composting or incineration with power generation at the final disposal sites.

Recycling and Reuse:

In a developing country like India, paper, plastic, glass, rubber, ferrous and non-ferrous metals – all the materials that can be recycled – are salvaged from the waste to produce low cost products extensively used by the lower income groups of the society.

Recycling has been receiving increasing attention worldwide over the past few years. Though the consumption of packaged goods in India is very low compared to that in the developed world, recycling has always been a common practice a part of India's cultural ethos. Selling old newspapers, magazines, books, empty bottles of glass and plastic, metal cans, etc. is common across all income groups at the household level. The emphasis has been changed to 'recover and recycle' from 'recover and reuse' due to the changing lifestyles and attitude of people to the kind of products they use. Of the wide array of recyclable materials present in Indian household wastes, it is paper and plastic that gets maximum attention, because the two together form the single largest component of household waste.

Recycling Plastic:

Over the last decade of the previous century, production and consumption of plastic has increased more than tenfold; between 1960 and 1965, the increase was more than 70 times (TERI, 1998). Consequently, the share of plastic in the waste has been rising rapidly. According to a primary survey done by TERI in

1996, plastic was accounted for 4 to 9 percent of the waste across different income groups of the country; while in 1971, it was only 0.7 percent.

The plastic industry is raw material intensive as the raw materials accounts for about 70 percent of the total production cost. Therefore, plastic recycling can save large quantities of petro-based virgin material. Overall, the annual consumption of plastic is less than 2 Kg per head, compared with the world average of 16.7 Kg and the developed-world average of 80 Kg (TERI, 1998). However, India recycles about 40 percent of its total plastic waste compared to a figure of only 15 to 20 percent in the developed world (TERI, 1998). But till date this sector faces various problems pertaining to governmental support, specifications regarding recycled content, etc. and thus plastic waste recycling continues to be a disorganised and technically backward sector.

Recycling Paper:

Due to the shortage of raw materials, high capital investments, large energy requirements, and environmental problems, paper are now being mainly made from agricultural residues and waste paper rather than from wood pulp. Agro-pulp and waste paper together accounted for 62 percent of paper production capacity in 1995 as compared to 35 percent in 1985. However, paper mills generally prefer to use imported waste paper because of the poor quality of domestic waste paper. For instance, each ton of imported waste paper can produce as much as 0.9 ton of recycled paper, which is considerably higher than the figure of 0.4 ton for agro-pulp and 0.5 ton for wood pulp (TERI, 1998). Given the current stress on liberalisation and industrial growth, and the changing lifestyles, consumption levels have increased significantly. But, compared to the developed nations, per capita consumption of paper and the proportion of paper in total waste generated are much lower in India like any other developing countries. Considering the environmental friendliness of waste-paper-based production, this sector should be encouraged more. Unfortunately, even the major metropolitan cities in India have not been able to augment the recovery, sorting and bailing of waste paper properly. The recovery and recycling of waste paper has received little support, either institutional or governmental.

In the absence of financial incentives and the latest technology, paper-recycling industry remains an undeveloped industry.

Recycling Glass:

Glass is another component of municipal solid waste that is normally recycled. It is usually picked up by rag pickers and reaches the glass industry through dealers. Waste glass is generally used in producing containers and hollow wares, sheet glass and flat glass, which account for most of the glass production. The proportion of waste glass in raw materials varies from 25 to 90 percent (TERI, 1998).

Apart from these services as mentioned above there are some other activities that are closely related with MSW management. In parallel to the formal system of waste management, there is an active informal network in Indian cities (CREED 26). This sector contains the waste pickers, Itinerant Waste Buyers (IWB's), waste dealers and wholesalers, and small recycling enterprises. The sector is driven primarily by market forces, and makes a significant contribution to the overall waste management process in Indian cities. Moreover, since the sector is labor intensive, it provides employment opportunities to a large group of people, accounting for an estimated 1-2 percent of the workforce in large cities (Furedy 1992). Although the role of the informal sector in waste collection is quite significant, the problem of solid waste management still lies in the partial collection of waste and inability of municipalities to handle the problem efficiently (Ravindra 1993).

Financial Aspects and Private Sector Participation:

Although local bodies have the power, under the laws, of levying certain taxes to raise their financial resources, they do not tap them adequately. In most of the cities, even the existing taxes are not collected or assessed properly. Mainly due to lack of political interests of imposing a specific tax for municipal services related to MSW management, steady deterioration of the system occurs in almost all the places. The increase in cost of services is not correspondingly met by an increase in tax recovery. Besides, there is an element of large-scale tax evasion and grave delays in assessing new buildings, which is not curbed

effectively. Presently some initiatives have been taken by both the central as well as various state governments after realising the importance of the issue. In doing so local bodies have compelled to introduce public-private partnership or private sector participation in the service. Presently private sector participation is being attempted in getting vehicles on contract and at some places contracts are being given for collection and transportation of waste and also for treatment of waste through recycling, composting, etc.

Initiatives Taken at the National Level:

Driven by the necessity, from government's side, some initiatives have also been taken to deal the matter efficiently. At different point of times government attempted to implement many policies for better waste management through various options like campaigning, setting up of expert committee, enforcing rules, etc. The followings are the major steps taken by the government in order to make the system smooth in functioning municipal activities.

The National Environment Awareness Campaign (NEAC):

The NEAC launched by the Ministry of Environment & Forests, Govt. of India in 1986 is being continued till date. The campaign is conducted on the identified environmental theme. Non-governmental organisations, education and training institutions, professional organisations, scientific bodies or government departments actively participate in the campaign. These bodies singularly or in partnership with other organisations, organise programmes for creating environmental awareness at the local level throughout the country. NEAC is a flagship environmental awareness campaign of the Government at the grass root level involving thousands of NGOs, voluntary agencies, educational institutes and others. The campaign is conducted on an identified environmental theme. The activities are aimed at spreading environmental awareness, which could lead to remedial actions from the individuals and society. NEAC has two components, namely, awareness campaign and action oriented component related to the identified issue involving local people. But the progress of the programme is not much satisfactory at all and that is evident from the present environmental situation of the country.

The Report of the Expert (J L Bajaj) Committee of Planning Commission May 1995:

The Planning Commission, in aftermath of the plague outbreak in Surat in September 1994, constituted a High Power Committee on solid waste management with Prof. J L Bajaj, Member, Planning Commission, as Chairman with eleven others expert members, to undertake an in depth review of the multi-dimensional issues concerning SWM in India and suggest suitable models for the development of cost-effective and environment-friendly approaches to promote sanitary methods of collection, transportation and disposal of solid waste in Indian cities and towns, especially those, with a population of more than on million inhabitants. The report concluded, "A situation analysis of the existing state of waste management in the Indian cities and towns would lead to inevitable conclusion that better sanitation standards could have been achieved in most of our cities and towns by prudent and planned allocation of available resources to develop and support the application of appropriate low cost, eco-friendly technologies" (Planning Commission, 1995). The Committee had suggested an action plan for the last two years of the Eighth Five-Year Plan which included measures for technological improvement, financial requirement, strengthening and modification of municipal by-laws to ensure safe disposal of urban wastes, institutional set up for coordinating and monitoring the activities relating to SWM development of a technological institution for research and development of human resources with proper training and so forth.

Interim Report of the Committee on Solid Waste Management in Class I Cities in India Constituted by the Supreme Court of India, June 1998:

In response to the directives issued by the Supreme Court against the PIL Writ Petition No. 888 of 1996 by Mrs. Almitra H. Patel and Another vs. Union of India and Others, seeking directives from the apex court to the urban local bodies as well as the Government of India and the state governments in the country for improving solid waste management practices, The Ministry of Urban Affairs and Employment of the Government of India constituted a committee of eight members on 29 January 1998 with Mr. Ashim Burman, Commissioner, Calcutta Municipal Corporation as Chairman for looking into all aspect of garbage management in all class I cities.

The Committee submitted an Interim report in June 1998, which contains deliberations on the present scenario in garbage management and detailed recommendations on various technical, institutional and social aspects of storage, collection, transportation and disposal of garbage in Class I cities. The Committee finds that the collection efficiency of municipal authorities, who are statutorily obliged to provide these services, is lower than 50 percent in many cities. According to the Committee, the most problematic area in managing MSW is the absence of coordination between the employees, stages of operation and the equipment used for the SWM. A proper and systematic synchronisation of the sets of workers involved in performing the services relating to SWM should be done to overcome the backlog and accumulation of uncollected wastes at different points. Moreover, its recommendations include steps for strengthening the institutional set-up, management information system and financial and legal provisions. The Committee also recommended certain specific responsibilities not only for the local, state and central governments, but also for the citizens and the community.

Municipal Solid Waste (Management & Handling) Rules, 1998:

The Government of India, in exercise of the powers confined by sections 3, 6 and 25 of the Environment (Protection) Act, 1986 (Act 29 of 1986) issued a Notification on the Management of Municipal Solid Waste (Management & Handling) Rules, 1998. The Rules prepared by the CPCB in June 1998, is applicable to every municipal authority and/or any other authority designated for the management of municipal solid waste.

The Rules gives in detail the compliance criteria for collection, segregation, transportation, processing and disposal of municipal solid waste with specification of disposal of solid waste through sanitary landfill and the norms to be followed for environmental protection in and around the sanitary landfill.

In crux, the overall performance of the MSW management in India can be characterised by poor performing formal sector with extensive involvement of informal sector.

The problem of municipal solid waste management is also acute in many other countries, both developed and developing. The extent of the problem differ form country to country, even within a country, from place to place. More or less all the developing countries posses some common characteristics regarding this issue, viz. relatively high organic contents, significant proportion of earth and inert, lower proportion of recycled items, etc. Whereas, developed countries facing the problem of MSW management since earlier, efficiently manage this issue with technical modifications and financial up gradation. In the next section, we will mainly discuss the problem of municipal solid waste management in developing countries with necessary reference of advanced countries where possible.

B. Solid Waste Management in Developing Countries

Developing countries now a day are also experiencing the trend of rapid urbanisation and population growth. For instance, while in 1960's only about 20 percent of the developing countries population used to live in cities, it has been estimated that about 60 percent of them would live in cities by the year 2020 (Rapten, 1998). Consequently, they will face financial and institutional constraints to manage the resulting solid wastes. Municipal solid waste management system in many cities is rudimentary. Though, on an average, solid waste management accounts for 20-50 percent of the municipal budget, the service is provided for 50 percent of the urban population, collecting only 60-70 percent of the refuse (Cointreau-Levine, 1994).

The quantities and characteristics of solid waste produced vary from country to country, and from city to city. Factors influencing the quantities and composition include average level of income, sources, population, social behavior, climate, industrial production and the existence of the market for waste materials. Waste densities and moisture contents are much higher in developing countries, which require different technology and management system (Cointreau et al. 1983).

The difference between solid waste management in advanced and developing countries can be framed in three parts viz. waste generation; waste collection and disposal; and waste recovery and recycling.

Waste Generation:

Given the food habit, socio-economic profile and climatic condition, per capita generation of MSW is much lower in developing countries than that of in developed countries. Differences also arise between high and low income countries in terms of waste composition and physical characteristics of waste. Table 3.9 shows the difference in these items between the developed and developing countries.

Table 3.9: Difference in the Composition of Municipal Solid Waste

Category		Bangkok	Dar Es Salaam	Jakarta	Mexico City	USA
Paper		12.4	6.2	2	19.2	32.3
Food Waste		39.2	62.5	60	43.1	8.1
Textiles		3.2	1.8	.	5.7	3.3
Plastics		9.4	0.3	2	5	9.8
Leather/Rubber		1.9	.	.	.	2.7
Metals		1.7	1.2	2	3.7	7.7
Glass		3.2	0.3	2	8.4	6.5
Miscellaneous		29	27.7	32	14.9	29.6
Landfill Density (Kg/cu. m³)		615	980	1000	640	460
Potential Landfill Utilisation Rate (cu. m/capita/year)		0.5	0.3	0.2	0.6	1.3
Biodegradable	Percent by Weight	67	69	62	66	67
	Moisture Content	31	44	42	34	20
	C /N Ratio	88	32	24	49	90
Energy Content of MSW (Kilojoules/ Kg)		11300	6300	6000	8900	12900

Figures, unless stated otherwise are in percent.
Source: Beede and Bloom (1995).

Table 3.9 demonstrates that food waste represent the largest portion of MSW in developing countries. By contrast paper accounts for a much smaller share of MSW, reflecting relatively less per capita consumption of packaged goods, office papers, newspapers and magazines compared to United States. The higher food waste content of MSW (biodegradable) in the cities of developing countries is

more or less offset by the lower paper content. Biodegradable materials are important to the economics of MSW management because they may be converted through microbial activity into either methane, which can be captured and used as fuel, or into compost. The Carbon to Nitrogen (C/N) ratio of the biodegradable portion of MSW is an important determinant of the speed (and therefore the cost) of composting. The optimal C/N ration of 25 to 1 is substantially exceeded for all the locations except in Jakarta and Dar-Es-Salem. The table also indicates that the energy content of MSW in developing countries is relatively low because of its high moisture content. Thus incineration, as a policy option, would be ineffective in managing solid waste in developing countries. Landfill density is much lower in case of advanced countries, showing the technical advancement in their system that could compress a large volume of waste into a smaller one by using necessary machineries. Moreover, developed countries generate more waste that results in higher rate of landfill utilisation per capita per year and according to the figure given in the above table that rate is around 2 to 5 times more than other part of the world.

Table 3.10: Changes in the composition of Solid Waste

Countries		Components (in percent)					
		Compostable	Paper	Plastic	Glass	Metal	Others
Low Income	Myanmar	80	4	2	0	1.9	14
	India	41.8	5.7	3.9	2.1	1.9	44.6
Middle Income	Indonesia	70.2	10.9	8.7	1.7	1.8	6.2
	Philippines	41.6	19.5	13.8	2.5	4.8	17.9
High Income	Japan	26	46	9	7	8	12
	Hong Kong	37.2	21.6	15.7	3.9	3.9	17.6

Source: Hoornweg *et. al.* (1999).

But things have also been changed in case of developing countries due to the impact of globalisation. World Bank projection find that waste composition in developing countries is likely to become more variable as the percentage of compostable matters decline and packaging wastes, especially papers and plastics, increase due to changed consumption pattern influenced by high annual growth rate of GNP. Table 3.10 shows the change in waste composition

for low-income, middle-income and high-income countries from the projected data.

Table 3.10 shows that over time as low and middle-income countries have become more urbanised, their waste composition have got tilted in favour of paper and paper packaging. The next most significant thing is observed in the quantities of plastics, multi material items, and 'consumer products' and their related packaging materials.

In addition, presence of the hazardous contents in the waste of developing countries is quite high as the regulatory and enforcement system to control such disposal are usually non-existent or not operating (Cointreau-Levine, 1994).

Waste Collection and Disposal:

In advanced countries municipal solid waste management techniques are capital intensive, knowledge based and infrastructure intensive as well. The most capital intensive method is mixed collection system in which MSW is collected and delivered to a facility that extracts recyclable materials by using necessary instruments; the remainder are often used to make fuels for electricity generating incinerators. In contrast, collection and processing methods of recyclable materials are labor intensive throughout the developing world.

The level of services for waste collection also varies markedly between developed and developing nations. In most advanced countries, over 90 percent of the total populations have access to waste collection system. On the other hand, official waste collection systems in developing countries are largely inefficient, with substantial amount of refuse left uncollected in many urban areas. Moreover, poorer communities in slum settlements, who have little potential influence, are often left out of municipal services. It is estimated that, even though MSW management accounts for 20 to 50 percent of available operational budgets for municipal services in developing countries, but only 50 percent of the urban population is served and only 60 to 70 percent of the refuse are collected (Bartone *et. al.*, 1990).

Table 3.11: Waste Disposal Options in Developed Countries

Countries	Total MSW Collected*	Disposal Options (Percentage of MSW Collected)				
		Mechanical Sorting	Compost	Incineration	Landfill	Other
Denmark	2400	15	.	55	30	.
France	17000	.	7.1	41	45.2	6.7
West Germany	19843	.	2.2	30.5	66.3	1
Japan	50609	.	0.1	64.4	32.6	2.8
Netherlands	46900	3	5	37	55	.
Sweden	2750	9.1		50.9	40	.
U.K	200000	12.5	.	12.5	70	.
Canada	16000	.	.	9.5	84	1.5
USA (1996)	208760	.	.	7	66	.

* In '000 Tons
Source: Turner (1995).

In many developed countries, burial in controlled landfills continues to be the most prevalent means of disposing of solid wastes including hazardous wastes. Incineration and recycling also play a key role in the management of urban and industrial wastes. The following table shows various waste disposal options practiced in developed countries.

From the information given in Table 3.11, it can be inferred that incineration as a disposal option is particularly popular in densely populated countries like Japan and Netherlands. Moreover for all of the above countries landfill features as an equally good option. But, here, keeping in mind that, area required for land filling is decreasing day by day and air pollution is generated as externality from incineration, the option of composting should be practiced further for the type of waste where organic part is high in proportion.

In contrast, in developing countries the prevalent methods of solid waste disposal are the uncontrolled dumping and burning on open ground and city streets (Cointreau-Levine, 1994). Difference also exists between developed and developing nations regarding disposal costs. The disposal costs for different country groups accounting for 0.2 to 0.5 percent of GDP, which are sufficiently high, especially for developing countries (Pearce and Turner, 1994). The

comparative figures of average costs of waste disposal in low income, middle income and high-income countries are shown in Table 3.12.

Table 3.12: Cost of Municipal Waste Collection and Disposal ($ per ton)

	Country		
Cost Items	Low Income	Medium Income	High Income
Collection	15-30	30-70	70-120
Disposal	1-3	3-10	15-20
Transfer	3-5	5-15	15-20
Total (maximum)	19-38	38-95	100-190
Disposal Cost /	0.2-0.4	0.2-0.5	0.2-0.4

Figures are in percentage.
Source: Pearce and Turner (1994).

For developing countries, the irony lies in the fact that, though policy makers are well aware about the issues of lack of basic infrastructures like water supply, waste water treatment, inefficient working of solid waste collection system, etc., they merely regard these things with priority and take necessary steps such as construction, operation and maintenance of water purifying systems, effluent treatment plants, sanitary landfills, etc. So the urgency of tackling the problem regarding municipal solid waste management emerges in the developing part of the world where things have not dealt with proper attention even in present days. Given the problem related to smooth performance of municipal services, the issue of MSW management should be undertaken by the authority with sufficient necessity. In doing so, we must have adequate information regarding municipal services for a particular place to analyse the situation. In the next chapter, we will discuss the case study of the city Delhi, which being the national capital territory of India, is highly urbanised with dense population. There we will show the extent of generation of municipal solid waste for the future years so that necessary steps can be taken to deal that given the constraint of landfill capacity around the city.

CHAPTER IV

The Case Study of Delhi

Introduction:

In the last chapter we have broadly discussed the problem related to municipal solid waste management for India as a whole and also for some other developing countries with special reference to some advanced countries where possible. Here, in this chapter, our goal is to put some light on this issue in a different way. As we told earlier, till today India, along with many other developing countries, considers municipal activities like collection, disposal, treatment etc. as social activities. That is why municipalities /municipal corporations use to charge a flat fee to each household in order to finance the costs associated with these activities. The main problem pertaining to this type of cost financing is that it does not depend on the extent of generation. But considering the current trend of urbanisation, burgeoning population level and scarcity of free plots, we should consider this problem of municipal solid waste management with high importance unless it will be too late to do anything. Having faced by this problem, developed countries have already adopted many such measures as economic instruments of charging taxes for using virgin materials or giving subsidy for reusing any product, enforcing command and control policy or adjustment between the polluting party and the local authority. Adoption of any particular instrument or combination of more than one instrument needs adequate information about the amount of waste generation and also about its physical and chemical characteristics. But in India, like many other developing countries, sufficient information in this field is not readily available. Except some few cities, there are no such records that maintain information regarding municipal solid waste generation for large cities over the years. Some studies (Bhide & Sundaresan, 1973; NEERI 1996; CPCB 2000; ISS 2000;) revealed some information related to this matter but that were mainly for some specific cities of particular years. Taking these issues in mind, our main objective is to predict the extent of the problem for future so that it would be easier for the policy makers to determine the effective instruments in

order to deal the problem. Along with that we have also shown the relative dependence of the factors like population, per capita income and public expenditure on the level of municipal solid waste generation at the aggregate level. On the basis of the results derived from this relationship the concerning authority can prioritise the available options to achieve the goal of well performing municipal system. Since till date there is no such economic instrument applied in Indian context, though it should already have, it is the crucial time to think about the way out of the problem. Driven by this necessity we, in this chapter, have focused on the future trend of municipal solid waste generation for the city Delhi. For our case study, we have chosen the city Delhi mainly due to the high standard of living lead by its cosmopolitan society along with the burgeoning population rate that the city has been experiencing over the decades.

We have segmented this chapter along with this introduction into following sections. In section A, we discuss about the profile of the city Delhi and some related necessary information. Section B deals the organisational structure of the municipal authority of the city. Then various operations regarding managing municipal solid waste of Delhi have been discussed in section C. The next section consists of the main matter i.e. modeling and the associated results with analysis.

A. Profile of the City Delhi:

Delhi, being the National Capital Territory (NCT) of India is one of the fastest growing metropolises in the country. The city sprawls over an area of 1483 sq. km. (Census of India, 2001) and is bounded by the states of Haryana on its west and by Uttar Pradesh in the east. Its maximum length and width is 51.9 km. and 48.48 km. respectively (Singh, 2001). Being the core 'area of political, financial and economic interests', population of Delhi has been growing drastically over the years. The scenario can be further elaborated by the figures shown in Table 4.1 that initially, population of Delhi barely increased from 0.41 million in 1911 to 0.92 million 1941 and then almost doubled to 1.74 million in 1951, registering decadal growth of 90 percent (apprx). Since 1941 the city's decadal population growth always hovered around 50 percent on an average,

except in 1951 when sudden influx of migrants due to Partition shot up the decadal growth rate to almost 90 percent. Then onwards, in the next four decades the decadal growth rate had constantly been above 50 percent and had resulted into a population of 9.42 million in 1991. According to the Census of India, 2001, the city had 13.85 million populations with a growth rate of 47.02 percent, as against the corresponding all India level, which is 27.8 percent (Census of India, various issues).

The city is also growing with commercial as well as industrial and associated tertiary economic activities that result in a rapid phase of urbanisation. The rate of change in urban population is very significant over the years for the city Delhi. The percentage of total population staying in urban areas has increased from mere 57.5 percent in 1991 to as high as 92.73 percent in 1981 and according to the Population Census 2001 the current figure is 93.01 percent, the highest in India. Given the urbanisation rate, the land required for the new settlement has not risen to that extent, which results in drastic change in population density. There were only 279 persons per square kilometer lived in Delhi in 1911 as compared to national average of 82 and now in 2001, the population density for the city Delhi is 9340 while the all India average is 324.

Table 4.1: Population Trend in Delhi over the Last Century

Year		1911	1921	1931	1941	1951	1961	1971	1981	1991	2001
Population*		0.41	0.49	0.64	0.92	1.74	2.66	4.07	6.22	9.42	13.85
Decadal Variation#			18.03	30.26	44.27	90	52.44	52.93	53	51.45	47.02
Urban Population*		0.23	0.3	0.44	0.69	1.43	2.35	3.64	5.76	8.47	12.9
Percentage of Urban Population#		57.5	62.32	70.32	75.78	82.4	88.75	89.70	92.73	89.93	93.2
Population density@	Delhi	279	318	429	617	1165	1792	2738	4194	6352	9340
	India	82	82	90	103	117	142	177	216	267	324

* Population figures are in million. # Figures are in percentage. @ Figures are in number.
Source: Census of India, Various Issues.

For a city like Delhi, with that much of urbanisation rate and population density has an immediate impact on the lifestyle of the people living here. As a natural process people here are prone to adopt all the characteristics of western

speedy life that is far different from many other places of India. Changes in the lifestyle of the people stemming from consumerism have resulted in increased wasteful consumption, leading to an increase in the quantum of solid waste generation. Along with the intrinsic population growth the rural to urban mass migration account for additional population pressure on the city. As the national capital it attracts people from all over the country in search not only of economic opportunity but also of educational advancements, health and medical facilities, family ties, etc. with which it is better endowed than most other states of the country. It is to be noted that in between 1981-91 almost 50 percent of the additional population was contributed by migrants (Singh, 2001). The migration has taken place mainly from Uttar Pradesh (39.44%), Haryana (11.57%), Rajasthan (6.41%), Himachal Pradesh (1.7%) and far of backward states like Bihar (3.26%) (Census of India, 1991). The situation is further aggravated due to indiscriminate growth of informal settlements wherein 49 percent of the population currently resides (Agarwal *et. al.*, 2005). These mushrooming settlements have developed in an unplanned manner and have imposed severe constraints on municipal services such as, water supply, sewerage, and collection and disposal of solid waste. Municipal agencies, due to organisational and financial constraints, usually take any effective step as and when problems are highlighted. Such an approach has effectively prevented emergence of an efficient solid waste management system, a system that receives low priority from the planners on account of preferential treatment given to provision of essential services such as electricity and water (Agarwal *et. al.*, 2005).

B. Organisational Structure:

The provision of basic services is primarily the responsibility of the three local bodies in the National Capital Territory (NCT) of Delhi – the Municipal Corporation of Delhi (MCD), the New Delhi Municipal Council (NDMC), and the Delhi Cantonment Board (DCB). Among these three, the MCD is the largest local body with responsibility of providing the basic amenities to 95.80 percent of the total population from both urban and rural background living in the areas encompassing 1397.3 sq. km. or 94.2 percent of the whole NCT area (ISS, 2000;

Sarkar, 2003). The NDMC, covering an area of 42.74 sq. km. (2.88 percent), accounts for 3.20 percent of population while DCB oversees an area of 42.97 sq. km. (2.92 percent) and accounts for just 1 percent of the population.

Among these local bodies, MCD is the only elected body, whereas the NDMC does not have the status of a proper local body as its entire members are nominated. It consists of the core administrative and residential area having national importance. The DCB is entirely financed and controlled by the Ministry of Defence of the Central Government. The MCD is among the largest municipal bodies in the world with respect to population. It is next only to Tokyo in terms of area. The provision and maintenance of municipal services in NCT of Delhi vest within three above mentioned local bodies. Among these, the MCD has sole responsibility to provide the basic services not only to urban areas but also to the rural population. The above authorities are supported by number of other agencies. The Delhi Development Authority (DDA) is responsible for siting and allotment of land to MCD for sanitary land filling. Delhi Energy Development Agency (DEDA) under Delhi Administration (DA) is responsible for solid waste utilisation projects aiming at biogas or energy generation in consultation with Department of Non-Conventional Energy Sources (DNES), and Ministry of Environment and Forests, the Government of India. The Department of Flood Control of Delhi Administration looks after the supply of soil to be used as covered for sanitary landfills by the MCD. Besides, Delhi Government, Resident Welfare Association (RWAs), Non-Government Organisations (NGOs), etc. are also working in the field of solid waste management system.

Apart from the above public and private organisations there are other important agents who play their part in the overall scheme of solid waste management of the city. They are private sweepers and garbage collectors employed by the people for cleaning privately owned premises, waste pickers, waste dealers and recycling industries, which consume recyclable waste to produce recycled products.

MCD has a separate department known as Conservancy and Sanitation Engineering (CSE) Department, which is responsible for the solid waste management and storm water disposal management. The department is headed

by a Director-in-Chief under whom the whole CSE staff work. There are two Directors in the department; one is for looking after 7 zones and the other for 5 zones of the MCD. There are six Joint Directors for the different zones under whom supporting staff assist them in all technical matters. Apart from this, there are Sanitary Superintendent, Chief Sanitary Inspector, Sanitary Inspector, Assistant Sanitary Inspector, Safai Guide, Driver and Safai-Karmacharis (regular and daily wagers). The Sanitary Superintendent looks after the work of collection and transportation of solid waste and storm water disposal management in their zones and submits the report to the concerned Joint Director. Apart from this, they are responsible for redressal of complaints related to collection of solid waste that are received by the Additional Deputy Commissioner. According to a study by NEERI (1996), the engineering staffs devote more time in solving the problems related to the old sewerage system of the city and are, therefore, not able to provide adequate attention to the supervision activities related to SWM. Hence, they have to depend on the conservancy staffs for the operation of the SWM system.

C. Municipal Solid Waste Management in Delhi:

Managing municipal solid waste is basically refers to the services like collection, transportation, disposal, and recycling of refuse. Here we will discuss all these issues along with the generation of end-use of the city Delhi.

Generation:

Solid waste management refers to the process right from the collection to the disposal. It has already been told earlier that, amount of municipal solid waste generated depends upon number of factors like population, life style, socio-economic structure, geographical condition, etc. The garbage generated in Delhi consists of heterogeneous items like, food waste, paper, cardboard, plastic, textiles, rubber, leather, yard waste, wood, glass, tin, aluminium, other metals, dirt & ash, etc.

Among these, the biodegradable components (i.e. food waste and yard waste) are the principal factors of MSW in Delhi with as high as 47.07 percent by weight. Next to this is the filling component, i.e. dirt and ash, with 36.56

percent by weight. Recyclable components with 11.81 percent by weight are far lower in proportion. Composition of individual components of MSW in Delhi is given in the Table 4.2.

Table 4.2: Physical Characteristics of Municipal Solid Waste in Delhi

Components	Percentage (By Weight)	Weight (in TPM)
Food Waste	25.22	39966.03
Yard Waste	21.85	34625.61
Glass	0.49	776.50
Tin	0.20	316.94
Aluminium	0.00	0.00
Other Metals	0.25	396.17
Paper	3.62	5736.60
Card Board	3.08	4880.86
Plastics	4.17	6608.18
Textiles	0.52	824.04
Rubber	1.83	2899.99
Leather	0.37	586.34
Wood	1.72	2725.68
Dirt & Ash	36.56	57936.48
Total	**99.88**	**158279.42**

TPM: Ton Per Month
Source: Compendium of Environment Statistics, 2001

The average per capita waste generation in the city is about 765 grams (Singh, 2001). If we include the garbage of illegal colonies in the city, the figure will be even higher than that. While, the MCD, on an average, collects around 5500 metric tons of solid waste daily, which increases up to more than 6000 metric tons during the festive season i.e. roughly about 400-450 grams per capita per day (MCD, 2005). Given this fact, it can be said that there is a wide gap between waste generation and collection that has led to very unhygienic conditions and a deteriorated quality of the urban environment (Times of India, 27th Sept. 2003).

Collection:

While the local bodies in some states are usually responsible for all the three components of municipal solid waste management process, namely, collection,

transportation and disposal, the Conservancy and Sanitation Engineering (CSE) department of the Municipal Corporation of Delhi is not statutorily responsible for house-to-house collection of garbage. Under the Section 353, Clause (B) of the Delhi Municipal Act, it is the responsibility of the owners and occupants to deposit garbage in the receptacles provided by the local body. Moreover, factories and workshops are responsible for collection and disposal of waste generated there in the same manner that applicable for households. The street sweeping work is carried out manually and the collected waste is deposited in community bins located at different points. The community bins comprises roofless structures called dustbin and large sized roofed structures referred to as 'dalao'.

The department collects waste from different dalaos, dustbins and open spaces of the city. There are 2500 dalaos/dustbins/open sites in the city, which is insufficient to put the huge quantity of waste generated. Due to non-availability of dustbins in some areas, the open spaces are converted into dustbins. The people are responsible to deposit their waste into the municipal receptacles. Most of the people hire private sweepers for the purpose. It is mandatory for household and shopkeepers to segregate the waste into biodegradable and non-biodegradable waste and put into the two different colored bins, i.e. green and blue. Non-biodegradable waste should put into the blue color coded bins and biodegradable should put into the green color coded bins. The MCD installed two colored waste containers in few areas of the city in order to create the habit of segregation of waste among the people. But in reality, the system is not working very smoothly, causing a large gap between generation and collection of solid waste. Table 4.3 shows the difference between generation and collection of solid waste as estimated by NEERI, 1996 and MCD, 1998.

In the Table 4.3, the amounts of garbage generated were calculated on the basis of 450 grams per capita per day as the norm for generation of garbage according to the CSE (ISS, 2000). Following that measure, the backlog was 1616.95 ton i.e. 31.2 percent of generated waste remained uncollected in the year 1996 and that of in 1998 was 9.5 percent. But there is no confirming figure

about per capita per day waste generation available till date. According to Singh, 2003, including the informal settlements, the per capita daily waste generation is about 765 grams. On an average, according to the intuitive comments made by the experts, around 15-20 percent of total generated wastes remain uncollected.

Table 4.3: Garbage Generation and Its Collection by MCD, 1996 and 1998

	NEERI, 1996	MCD, 1998
Population (in number)	11483213	12281400
Garbage Generated @ 450 gm/capita*	5167.44	5526.63
Garbage Collected by the MCD*	3550.49	5000
Backlog (Generation – Collection)*	1616.95	526.93

* In Tons Per Day.
Source: NEERI, 1996 and MCD, 1998.

The waste generated is collected by the safai-karmacharis of the CSE department. Despite the huge army of staff, the Corporation is collecting roughly about 80 percent of generated waste and rest is uncollected. The collected garbage in Delhi contains a high percentage of silt (about 50 percent) and other inert materials and around 40-50 percent moisture. The cost of collection of waste is approximately Rs. 600/- per metric tons. Despite a huge expenditure on the solid waste activities, the Corporation could not earn revenue because there are no service charges or user charges for these activities.

Transportation of Waste:

The collected waste is then carried to the disposal places for dumping through the municipal vehicles, i.e. Tipper Trucks and Loader cum Trucks. Loaders, Hydraulic Excavators, Bulldozers, are also used for loading the vehicles from the dalaos /dustbins. It has been observed that around 75 percent of the total trucks are put to use everyday because of poor maintenance and old age of the fleets. NEERI's study of the MCD in 1996 revealed that about 20 percent of the total trucks were over seven years old, that is, beyond their economically viable life span. Moreover, garbage spills form the open trucks as

majority of them are not covered with tarpaulin, which are supposed to be used by every truck.

Disposal of Waste:

The disposal of waste is an important aspect of the solid waste management and requires proper attention of the city Corporation through effective and efficient planning. The waste collected from various dustbins or dalaos is disposed of by various methods such as dumping, sanitary landfill and composting.

Sanitary Landfill:

Filling components consists of 36.56 percent of total MSW by weight. This is mainly because wastes are dumped in an uncontrolled manner and thus plenty of dust and inert mix with that.

Table 4.4: Filling Components of MSW in Delhi

Filling Components	Percentage (By Weight)	Weight (in TPM)
Dirt & Ash	36.56	57936.8

TPM: Ton Per Month
Source: Compendium of Environment Statistics, 2001

According to MCD officials, in past, 16 sanitary landfill sites had been filled up with garbage and the same are being developed into Forestry/Gardens/Parks/Green area. At present there are 3 sanitary landfill sites in Delhi namely Bhalswa, Ghazipur and Bawana. About 60-70 percent of waste is actually brought to the disposal sites and the rest remain un-transported and littering the city. The average cost of waste disposal is about Rs. 200 per ton in addition to the Rs. 600 for collection and Rs. 200 as transportation charges. Delhi face the problem of overflowing landfill sites, which have almost exhausted their capacity, and the capital would need garbage dump in the near future. Therefore it is necessary to identify more suitable disposal sites with the adequate capacity and acquired to cover the requirements for the next 20-25 years.

Composting of Waste:

The organic part consists of major proportion of MSW in Delhi. According to the information given in Table 4.5, compostable matter by weight is almost half of the total waste generated. The existing amount of Carbon and Nitrogen makes the C/N ratio around 16 which far less than the ideal value of 25. Since the organic part is so high in MSW, composting is supposed to be a good option of treating the waste. But given the nature i.e. low C/N ratio, of the biodegradable components present in MSW, the experiences of treating them through composting were not good.

Table 4.5: Biodegradable Components of MSW in Delhi

Components	Percentage (By Weight)	Weight (in TPM)	Carbon (in TPM)	Nitrogen (in TPM)	C/N Ratio
Food Waste	25.22	39966.03	19183.70	1039.12	18.46
Yard Waste	21.85	34625.61	16551.04	1177.27	14.06
Total	**47.07**	**74591.64**	**35734.74**	**2216.39**	**16.12**

TPM: Ton Per Month
Source: Compendium of Environment Statistics, 2001

In 1980, the MCD under the Central Scheme for Solid Waste Disposal set up a mechanical compost plant in Okhla with a capacity of 150 tons per day. However, its working had to be discontinued in the absence of a market in the neighbouring areas and also due to the high operational cost of the plant. Later in 1996, driven by the directives of the Supreme Court of India, another plant was set up in Bhalswa through private operators with the capacity of 500 metric tons per day. In the presence of inappropriate system of disposal of waste in sanitary landfill, many experts committee including Jagmohan Committee, 1995 and the NEERI Report, 1996 have reiterated the need for recycling and processing waste by composting.

As one of the ways of processing the wastes, 300 tons per day incinerator-cum-power generation plant was set up in Timarpur in 1989 through the Department of Non-Conventional Energy Sources. However, its operation had to

be discontinued within a short period due to the low calorific value of the waste brought to the plant.

Recycling of Waste:

Among the recyclable materials of municipal solid waste generated in Delhi, plastic consists of the major percentage of recycling. According to the available information as given in the Table 4.6, only plastic, paper and cardboard are recycled to some extent, while recycling rate of glass, tin and other metals are negligible and officially, there is no information about aluminium recycling.

Mostly recycling of waste is done by the private operators through middleman including rag pickers who in the segregation of waste at different landfill sites in the city. The rag pickers in the informal sector are playing a significant role in the process of waste cleaning which is a common feature in the developing countries. They collect the recyclable materials form the waste and sell it to the middlemen at a nominal price. Then the middlemen sell it to the private firm for recycling purposes.

Table 4.6: Recyclable Components of MSW in Delhi

Components	Percentage (By Weight)	Weight (Ton/Month)
Paper	3.62	5736.6
Cardboard	3.08	4880.86
Plastics	4.17	6608.18
Glass	0.49	776.5
Tin	0.2	316.94
Aluminium	0	0
Other Metals	0.25	396.17
Total	**11.81**	**18715.25**

Source: Compendium of Environment Statistics, 2001

Currently more than one lakh people are attached with this profession and given their economic status and working condition; they are most vulnerable section of the society. Moreover, in order to minimise the health and safety risks of waste collection at the landfill sites, the Corporation does not encourage these people.

Finances of Municipal Solid Waste Management:

The MCD budget provides funds for the solid waste management under the head 'Public Health and Sanitation'. The solid waste management occupies a substantial part of the budget allocation i.e. 15-20 percent. But the large proportion of this allocation is incurred on the establishment cost that includes salary, allowances and other benefits to the huge staff of the CSE Department of the Corporation. Hence, despite the significant budgetary allocation, the fund needed for smooth running of the solid waste management is insufficient to keep the city clean. While the solid waste management has a high input cost, the MCD is not vested with the adequate resource considering the huge expenditure involved. The two main sources of income for the provision of this service are: (i) taxes, which are normally levied as part of property taxes, and (ii) proceeds from the sale of manure and compost. The taxes that are levied in lieu of waste disposal services are known variously as Sanitary Cess, Conservancy Tax, Scavenging Tax, Drainage Tax, etc. MCD levy Conservancy Tax, which is a part of the Property Tax to collect revenue required for performing municipal services. The revenue income from this source has fallen far short of the budget estimates. Despite that the MCD is not levying any independent tax on the provision of this service.

Under the circumstances as stated above, it is the high time to think about the matter with a fresh view in order to tackle the problem. In the following section we have discussed, in detail, about the analysis along with its importance and data analysis. There we have shown that generation of municipal solid waste depends on various factors like population, per capita income and public expenditure. To control the extent of waste generation, the government should concentrate in controlling the above mentioned explanatory variables. Moreover, in the next section we have also derived the level of municipal waste generation for future years. Along with these, importance of the issue and data analysis is also given there with sufficient explanations.

D. Analysis:

In this section we will discuss the importance of the analysis along with in detail description of the determining factors followed by modelling and results.

Importance of the analysis:

Given the factors like lack of places for land filling, paucity of funds to the municipal authorities and increasing trend of urbanisation along with gradual impact of consumerism, we should now think the problem of managing municipal solid waste in an implicit manner. First of all, we have to find the places where we should dump the end use; moreover, the capacity of the place should be high enough to absorb the volume of the garbage. Next, to deal the financial matter, we have to think of implementing some kinds of economic instruments that have been discussed in the chapter of 'literature survey' of this paper, on the basis of analysing the physical and chemical characteristics of waste otherwise financing the running cost will be tougher to tackle. These things can be done only when we have adequate information about the trend of waste generation along with its physical as well as chemical characteristics. Having these things in mind, we, in this chapter, focus on the trend of municipal solid waste generation through a forecasting analysis for future years on the basis of the month-wise data of the variable for as many years as available. Along with this we have also derived the relationship between municipal solid waste generation and population, per capita net state domestic product (PCNSDP) and gross state domestic product (GSDP). The rationales of taking these factors in determining the level of municipal solid waste generation are given in the following section.

Determining Factors:

It is very obvious that solid waste generation directly depends on the level of population and also on the standard of living. Places with high population level are likely to generate more waste. The problem is more acute in the places where population densities are also at a high level. Given the stories pertaining to municipal solid waste management of many developed countries, it became very evident that standard of living of the people of a particular area is a crucial factor in determining the generation of solid waste. To capture the effects of these two factors there is no doubt in considering the population level as one of the determining factors. Now, to have an impact of the standard of living we

have taken per capita net state domestic product (PCNSDP) as an indicator of income standard at the individual level.

The amount of municipal solid waste generation also depends on the factor like public expenditure by the government related to waste management activities such as more budgetary allocation for municipal services, setting up of waste treatment plants, introducing mechanised version of waste collection and related activities, initiating mass level campaigning for minimising waste, segregating them at the generation place, use of more recycled products, effectiveness of compost matter, etc. Since the proportion of the total budget allocated for MCD remains almost same over the years, we have taken gross state domestic product (GSDP) for the NCT of Delhi as a proxy to capture the effect of public expenditure on generation of waste. The rationale of taking GSDP as one of the dependent variables is that a higher amount of GSDP implies better workings of economic activities in that particular state. Now, with a good amount of GSDP, the particular state can initiate many programmes for economic and social betterment according to the priority level. That is, a state can implement some policies (e.g. running a recyclables treatment plant, campaigning against generation of more waste, etc.), which would be effective in dealing the problem MSW management in an improved manner. Moreover, with generally better performance, the economy as a whole can be in a position to afford the expenditures necessary for doing effective municipal services.

Hence, the variable gross state domestic product is incorporated here as a proxy of public expenditure by the state government. With a higher amount of public expenditure, the government can allocate more budgets for the public as a whole. Thus, any particular department can utilise the extra-allocated amount to various activities related to public services. For example, the municipal authority, with better budgetary allocation, can recruit more employees to make the collection process better or can introduce mechanised version of collection, disposal, and treatment of waste or can make extensive campaign for various policies like waste minimisation, source separation, more use of recyclable products and effectiveness of waste compost, or can set up modern equipped recycling plant, composting unit, sanitary landfill, etc. These types of actions taken by the authority often inspire the individuals in adopting all the necessary

environment friendly steps of MSW management. In this sense, the variable GSDP as a proxy of public expenditure is one of the crucial determinants of waste generation along with the variables like population and income.

Therefore, on the basis of the variables such as population, per capita net state domestic product and gross state domestic product, we run a regression model of ordinary least square (OLS) to show the level of dependence of these factors on the level of municipal solid waste generation. Before going into further details about the model specification, let us discuss the collection and analysis of the data that we have made in running the regression and the forecasting analysis. Problems that we have faced regarding the data for the variables incorporated in the model have also been stated here.

Data Collection and Analysis:

Since in our country, till date, people as well as the government are not much concerned about the problem of municipal solid waste management and also due to the existing structural and organisational loopholes, information related to this field are not at all available for several years even through private organisations.

Now in doing the analysis we faced various problems regarding data availability. One thing is that data itself is very insufficient to do any good estimation; moreover, there is a large discrepancy in data among various sources. In some cases, data given by one source is much smaller in volume than that given by other sources. It might be because of the fact that data were not collected on an aggregate basis; inference drawn from taking samples might be error full. Moreover, government does not publish any data related to MSW generation over the years; instead of what is available is some data for some years.

But, for the case of Delhi, things are not that much problematic. Here, Conservancy and Sanitation Engineering Department of Municipal Corporation of Delhi (MCD), driven by the urgency of the problem in present day's scenario, keeps month wise figure of municipal solid waste collection for the city Delhi as a whole. Since MCD covers almost 95 percent area of the NCT of Delhi, where 95 percent of the total population lives and as all the waste generated in NDMC

and DCB areas are finally dumped into landfill sites in the area under MCD jurisdiction, the data recorded by the CSE department of MCD basically shows the overall figure for the city. The problem with these data lies in the fact that month wise figure for aggregate collection of municipal solid waste is available since April 1991 as their working year spans from April to March. The concerning office bearer could not able to provide any month wise data before that period as the trend of maintaining the records regarding this issue was not a regular culture at that point of time. So we had to depend upon the data ranging from April 1991 to March 2005 to do our specific analysis. Here, we should keep in mind that, the CSE department of the MCD maintains records of MSW collected at the aggregate level in the city Delhi. There is no authentic source that reveals the actual difference between generation and collection of MSW.

For analytical simplicity, we are assuming that municipal authorities are performing their services properly; hence, collect all the refuse that are generated as the case should be at an ideal situation. So, in our analysis data of waste generation is assumed to be same with that of collection, though in reality the extent of generation might be larger than that.

Having year-wise data of the population figure for a particular state is not an easy task to do. On the basis of the population figure given by the Census of India, one can derive the year wise population figure but in that case one has to assume for simplicity, that the rate of growth of population remained constant over a particular decade. The results derived from using year-wise population figure by following this method are not logical in the sense that change in population with a constant rate can not represents the actual level of dependence of MSW on population. Considering this limitation, we preferred to collect the necessary year-wise population figure from the data base of *The Economic and Political Weekly Research Foundation* as they calculate the year-wise population figure that matches close with the actual figure on the basis of their own method that necessarily differs with assuming constant growth rate of population over a particular decade.

The data of per capita net state domestic product and gross state domestic product are easily available from the database of Central Statistical

Organisation (CSO), Government of India. But there are some problems in that data. These data are given with two base periods: with 1980-81 as base year, data are available up to the year 1996-97 and with 1993-94 as base; data are available only from the year 1993-94 till 2002-03. Now to make these two series comparable, following the usual way, we have computed the value of the deflators, which are basically the ratios of the figures with 1993-94 base and that of with 1980-81 bases. Since there are only four values available for both the series, i.e. from 1993-94 to 1996-97, we have derived the average value of the deflators for those four years. After calculating that, in order to make the old series (with 1980-81 as base) comparable with the newer one (with 1993-94 as base), values of the variable are multiplied by the average amount of the deflator for the years prior to 1993-94. Since MSW data are available only from 1991-92, we derived the corresponding value of per capita state domestic product and gross state domestic product for the years between 1991-92 and 1993-94 by adjusting through the average deflator, obtained from by following the method as stated above. And data of 1993-94 onwards are taken as provided by the CSO with base 1993-94. To improve the accuracy of our analysis we did not take data for the year 2003-04 and 2004-05 as they are provisional and quick estimates, respectively. So, for our analysis, we took the data of the variables municipal solid waste generation, population, per capita net state domestic product and gross state domestic product for the years 1991-92 to 2002-03.

Model Specification:

In this paper, our main objective is to forecast the amount of municipal solid waste generation for the future years of the city Delhi. Along with that, we have also shown the causal relationship between municipal solid waste generation and population, per capita net state domestic product, gross state domestic product as the last three variables should have significant impact, due to the reasons stated earlier, on the generation of MSW. But, data of MSW generation are available only from the year 1991-92. On the other hand, for the later periods, month-wise data are not available for other three variables though that is available for MSW generation.

Under the circumstances, what we did is that, we build up a linear regression model to show the level of dependence of municipal solid waste generation on population, PCNSDP and GSDP on the basis of year wise data from 1991-92 to 2002-03, and in doing the forecasting analysis with the month-wise data of MSW generation from 1991-92 to 2002-03, we have used the statistical theory of exponential smoothing, which is a very effective tool of making forecast in the presence of limited data source. Since we do not have plenty of information about the main variable i.e. municipal solid waste generation, we adopt the statistical technique of exponential smoothing which makes forecast on the basis of past forecast errors. Let us describe the theoretical modeling of the analysis along with the results.

Linear Regression Model:

Our basic modeling depicts a causal relationship between municipal solid waste generation and population, per capita net state domestic product, gross state domestic product. Here we build up linear model of ordinary least square to show the level of dependence of solid waste generation on population, PCNSDP and GSDP. Now, on the basis of the data from the years 1991-92 to 2002-03 for the variables municipal solid waste generation, per capita net state domestic product and gross state domestic product, we run the following regression model, considering MSW generation as the dependent variable and rest of the three as independent variables:

$$Y_t = a + b_1 X_{1t} + b_2 X_{2t} + b_3 X_{3t} + u_t$$

Where Y_t: Daily municipal solid waste generation (ton per day) of the year t.

X_{it}: Population (in thousand) of the year t.

X_{2t}: Per capita net state domestic product (PCNSDP) of the year t (in Rupees).

X_{3t}: Gross state domestic product (GSDP) of the year t (in Crore Rupees).

u_t: Error term associated in the model of the year t.

a is the associated constant term and

b_j's (j = 1, 2, 3) are values of the parameters corresponding to X_{it}'s.

From the above relation, we get the value of the corresponding parameters of the independent variables, which are discussed in the following section.

Results and Analysis:

After running the regression we get the specific values of the parameters along with the associated constant term and the equation-like form can be represented as follows

$$Y_t = (-21753.7) + (1.85)\ X_{it} + (1.23)\ X_{2t} - (0.78)\ X_{3t}$$

and the corresponding standard error, t value and significance level can be tabulated as

Variables	Parameter Value	Standard Error	't' Value
Population	1.85	0.52	3.51*
PCNSDP	1.23	0.32	3.37*
GSDP	-0.78	0.19	-4.08*

* At 1 percent level of significance.
R^2 = 0.89, Adj R^2 = 0.86, D-W = 1.90, F Statistic = 23.77, Akaike Information Criterion = 14.8

Now, from the results given above, it has become very clear that all the three variables i.e. population, per capita net state domestic product and gross state domestic product have a significant impact on municipal solid waste generation. The parameters population and PCNSDP are positively related with MSW generation at one percent level of significance as the case should be. But the interesting thing here is that gross state domestic product, which is considered as a proxy of public expenditure is negatively related with MSW generation at one percent level of significance. The reason behind is that, with a higher gross state domestic product, hence higher public expenditure, the state as a whole can initiate many activities pertaining to socio-economic interests. Since environmental issues, considering the overall situation of present days, is one of the prime most areas of interests, the government takes many necessary actions to deal the matter efficiently. In our area of interest, i.e. municipal solid waste management, government, with its limited scope of work due to financial and

administrative constraints, is trying to take effective steps to make the situation better than earlier. These steps mainly include constructing of recycling treatment plant, initiating public awareness programme like ban of plastic bags, use of recycled products and most importantly the need of minimising waste generation. The results show that the gross state domestic product is an important determinant of waste generation as, due to the above-mentioned logic, a mass level social awareness can be boosted up in order to face the problem with a strong hand. Moreover, with better economic situation as reflected by higher gross state domestic product, all agents of the economy in general, can afford higher expenditure necessary for performing the activities in managing MSW efficiently. The variable population is positively related with MSW generation as expected at one percent level of significance, which shows that higher the level of population higher will be the generation of end use, as it should be. Same logic is applicable for the variable PCNSDP that represents the impact of per capita income on waste generation. There, more the amount of PCNSDP more will be the consumption capacity of the individual. With higher consumption capacity, the individual is likely to consume more and as an obvious result generates more waste. So there has to be a direct relationship between PCNSDP and MSW generation like the result shows.

In our analysis, value of the Durbin-Watson statistic is 1.9. Here the number of observations is 12 and the number of explanatory variables is 3. With this set of parameters, the lower and the upper limit of the Durbin-Watson statistic at 1 percent significance level are 0.449 and 1.575[1] respectively. So the Durbin-Watson statistic derived in our model is greater than the tabulated upper limit, which means the null hypothesis of non auto-correlated error terms should not be rejected. Thus the presence of auto-correlated error terms in the model is ruled out. Now let us consider the second part of the analysis, which is about forecasting MSW generation for the future years.

As we have clearly told earlier that data for the variable MSW generation are not adequate enough to do any usual statistical analysis for forecasting purpose. The generation of solid waste for the future years can be forecasted by applying some special statistical techniques. Considering the inadequacy of

[1] Durbin-Watson statistic (Savin-White tables) in J. Johnston, *Econometric Methods*, 3rd. Edition, pp. 554.

data, here, we have applied the concept of exponential smoothing, which is basically a simple method of adaptive forecasting. It is an effective way of forecasting in the presence of few observations on which to base the forecast. The merit of this method over forecasting from regression models is that, in regression model fixed coefficients are used, but forecast from exponential smoothing method is adjusted on the basis of past forecast errors. Before going into further discussion about the analysis through exponential smoothing, let us have the idea about the theory of exponential smoothing.

Theory of Exponential Smoothing:

Exponential smoothing is a special type of statistical technique through which one can forecast any variable despite of having limited number of observation on which to base the forecast. There are five types of exponential smoothing, viz. single, double, Holt-Winters multiplicative, Holt-Winters additive and Holt-Winters no-seasonal smoothing. Among them the single exponential smoothing method is of one parameter and is appropriate for a series that move randomly above and below a constant mean with no trend or seasonal patterns. The double smoothing is also of one parameter but this method applies the single smoothing method twice (using the same parameter) and is appropriate for a series with a linear trend. The multiplicative smoothing, which is named after Holt and Winters applies three parameters and the method is appropriate for a series with a linear time trend and multiplicative seasonal variation. The other type of a smoothing is Holt-Winters additive smoothing, which also, like multiplicative smoothing, uses three parameters and is appropriate for a series with a linear time trend and additive seasonal variation. The last type of the smoothing analysis is Holt-Winters no seasonal method that uses two parameters. This method is appropriate for a series with a linear time trend and no seasonal variation. This method is similar to the double smoothing method in the sense that both generate forecasts with a linear trend and no seasonal component. The double smoothing method is more parsimonious since it uses only one parameter, while this method is a two-parameter method.

Now, in our data set we have month wise data of total municipal solid waste generation in Delhi from the year 1991-92 to 2003-04. It is quite evident from

the data set that generation of solid waste varies from month to month. Considering the year wise aggregate generation level, it has been found that except the significant changes of solid waste generation for the years 1998-99 to 2000-01, the generation of MSW more or less follows a linear trend over the years. And for the data of a variable like municipal solid waste generation, it is quite likely that seasonal changes are mainly of additive pattern, because, given the population pattern and income standard, solid waste cannot be generated with a multiple proportion for a particular city. So we have considered Holt-Winters additive smoothing for our analysis of estimating the future values of municipal solid waste generation. The end point of our analysis is the year 2025 to have a foresight about MSW generation during the quarter of the current century. Moreover, with a limited data source, statistical results will fail to predict the value of the variable for a sufficiently large period in advance. Let us discuss the method of estimating the future values of a variable by using Holt-Winters additive smoothing analysis.

Holt-Winters Additive Smoothing Analysis:

This method is appropriate for a series with a linear time trend and additive seasonal variation. The smoothed series $\hat{y}_t$ of y_t is given by

$\hat{y}_{t+k} = a + bk + c_{t+k}$,

where a: Permanent component (intercept),

b: Trend,

c: Additive seasonal factor

These three coefficients are defined by the following recursions

$a(t) = \alpha(y_t - c_t(t-s)) + (1-\alpha)(a(t-1) + b(t-1))$,

$b(t) = \beta(a(t) - a(t-1)) + (1-\beta)b(t-1)$,

$c_t(t) = \delta(y_t - a(t)) + (1-\delta)c_t(t-s)$,

where $0 < \alpha, \beta, \delta < 1$ are the damping factors and s is the seasonal frequency of the variable.

Forecasts are computed by

$$\hat{y}_{T+k} = a(T) + b(T)k + c_{T+k-s}$$

where the seasonal factors are used from the last 's' estimates.

Here, forecast are made of the variable $\hat{y}_t$ at any time t = T for any future period k considering the seasonal frequency s. In this model the value of the additive seasonal factor c is adjusted from last 's' estimates. Thus the method predicts future values on the basis of past forecast errors that are better than making forecast form regression analysis that is done on the basis of fixed coefficients.

Following the method stated above, we have derived the future values of MSW generation of the city Delhi. Results are given in the following section with sufficient explanations.

Results and Implications:

The amounts of MSW generation for the future years are stated in the table below. Here to represent the values in a simplistic manner we are showing the figures for the years 2010, 2015, 2020, and 2025.

Table 4.7: Projected Generation of Municipal Solid Waste in Delhi

Year	2010	2015	2020	2025
MSW Generation*	7424.553	8583.185	9741.818	10900.45

* Ton Per Day

The value of α that we get from the result is 0.62 which is an acceptable value because $\alpha = 1$, basically refers the fact that forecasted values depend only on the latest actual values. So for a good estimate it is required that alpha should be as small as possible.

The figures derived from the analysis for the future years show the level of MSW generation. As the available land for disposing off the waste becomes scarce day by day, the problem of managing MSW will become even tougher in future. The authority should take necessary arrangements to manage the amount of waste generation considering the forecasted level for future years. The forecasted value

is based on past figures that show a strong dependence of waste generation on the factors like population, per capita income and public expenditure as it is explained in the regression analysis. Considering this fact, effective initiatives taken by the government can result in significant reduction in the amount of waste generation. If the authority starts doing some actions like checking the population growth rate, increasing the budget for public expenditure, etc., that will automatically have an impact on waste generation rate. So the figure, after taking all the needed measures, might be less in future than the level projected here. Whatever we have shown here is based on the available data from 1991-92. So if the trend experienced since 1991-92 persists, the amount of municipal solid waste generation will be like the figures as given in Table 4.7.

Here, one thing should be kept in mind that our entire analysis is based on the assumption that municipal authority collects all the wastes that are generated, as it should be in an ideal situation. But in reality there still exists some gaps between the amount generated and collected. Whatever data we have collected is about total collected amount of MSW in Delhi by MCD as there is no authentic source of getting the figure of MSW generation. So, in reality the figure might be even larger than what is shown in projection.

Given our intention to show the impact of socio-economic factors like population, per capita income, and public expenditure on the amount of municipal solid waste and to predict the extent of the problem in future, our study suffice in explaining both the objectives in greater detail. Before wrap up the chapter let us have a quick look on what the other studies say about projection of municipal solid waste generation.

Comparison with Other Studies:

It is not the case that the present study is the introductory one regarding the matter. There are several other studies, which project the amount of future generation of end use. These mainly include projection by TERI, Master Plan of Delhi 2021, etc.

The analysis made by TERI was a very simplistic one. Assuming the daily per capita waste generation in 1995 as 456 grams (EPTRI, 1995) and per capita increase in waste generation as 1.33 percent, they projected that total waste

generated in 2047 will exceed 260 million tons for the country India as a whole. But the demerit of the study is, there is no all India base information about MSW generation through which it can be inferred that waste generation rate is about 1.33 percent and it is not necessary for waste to generate at a constant rate of 1.33 percent throughout the future period. So the analysis is based on a very simple method of estimation that is not logically viable.

There is another projected analysis for the city Delhi given in the Master Plan of Delhi 2021. There they have shown the targeted figures of MSW collection that is generated in the years 2009, 2014, 2019 and 2024. The Table 4.8 shows the comparative figures of targeted waste collection by MCD as given in the 'Master Plan of Delhi 2021' and our analysis of projected waste generation in corresponding years.

Table 4.8: Projected Generation of Municipal Solid Waste in Delhi

Sources	2009	2014	2019	2024
The Master Plan of Delhi 2021	7086	9000	11345	14302
Our Analysis	7193	8351	9510	10669

Figures are in ton per day.

Here for analytical simplicity it can be assumed that the figures shown in Table 4.8 as targeted waste collection by MCD is same with targeted waste generation because the Planners of the 'Master Plan of Delhi 2021' are assuming that at least that much of waste will be generated as given under the name of 'targeted collection'. Moreover, there should not be any intentional gap between generation and collection of MSW; otherwise the problem will be aggravated beyond limit.

From the Table 4.8 it is clear that forecasted figure for the year 2009 is more or less close for both the study, but as the time progress thereafter, rate of change in daily waste generation becomes much less in our study and there is a significant difference between the two studies in the amount of waste generation for the year 2024. In our analysis, we have already shown that municipal solid waste generation depends on the population figure as well as on the PCNSDP

and the GSDP with usual sign. Now, considering the growth of the state economy as a whole, it is quite likely that the state will take much more progressive steps in building up an environmentally sound social system in the coming years. Thus the important role of public expenditure comes into the picture and urgency of allocating more budget for municipal services, for various public awareness campaign has to be realised by the concerning authority. As we have shown that the GSDP is inversely related with MSW generation, the rate of increase of daily waste generation will have to be in a slower rate than the rate projected by the Master Plan of Delhi 2021.

As a concluding remark it can be said that socio-economic factors like population, per capita income and public expenditure should taken with prior importance to tackle the problem of municipal solid waste management. The rate of population growth has to be minimised in order to restrict the population level within assimilative range. Along with that, level of public expenditure should be broadened up to make the society more eco-friendly. Moreover, to manage the financial aspects pertaining to MSW management economic instruments have to be introduced. Though the introduction of economic instruments will be easier after having the necessary information regarding physical and chemical characteristics of MSW, but in the absence of such information in detail we had to depend on some broad ideas about those characteristics. Thus we need a better policy perspective for the management of MSW for the coming days. The necessary policy measures that should be taken for a well performing municipal solid waste management are discussed in the next chapter along with the concluding remarks of this study.

CHAPTER V

Policy Implications & Conclusions

Introduction:

It has become very clear from the discussion made in the earlier chapters that the problem of managing MSW is becoming tougher day by day. For a growing city like Delhi, we have shown that the extent of generation would be much higher in the coming future. Since overall living standard, for the country India as a whole, is tilting towards western pattern, this problem will be in a severe form for rest of the country as well. After having an idea about the future extent of the problem we should, unless sitting idle, take necessary steps to handle the issue efficiently. In doing so, we have to adopt number of policies, which could lead us towards desired direction.

There are plenty of options as policy measurements that could be taken by both the government and individuals. The basic problem faced by any municipal authority, mainly in developing countries, is paucity of funds. Due to financial constraint these authorities cannot satisfactorily provide the municipal services to the people. There are shortage of staff resulting in widening gap between generation and collection of solid waste. Poor quality fleets are unsuitable for number of necessary trips for removing the generated waste. Inadequacy of funds makes them invalid in setting up of new waste treatment plants or running any existing plant economically. Moreover, it has been shown in the analysis given in chapter four that extent of waste generation get reduced with higher amount of gross state domestic product. But in reality, the concerning body, i.e. MCD in case of Delhi, compels to allocate the bulk of their budget for the purpose of paying salary to the employees. The amounts left are not sufficient enough to provide adequate municipal services to the people. So the necessity of raising funds to cover up the costs associated with municipal activities comes into the picture.

Apart from that, some steps considering the technical as well as administrative, social and environmental aspects should be taken as a part of effective policy measurements. Because all the aspects should be considered with adequate importance otherwise, there will be lack of synchronisation

among the agents of different activities and that might cause breakdown of the entire system. To capture these issues, we will discuss about various policy measurements necessary for an efficient management of MSW in section A. In section B, concluding remarks of the entire study will be talked about.

A. Policy Measurements:

Considering the overall scenario of the MSW management of the city Delhi and also taking into mind about the growth of urbanisation that the city has been experiencing over the decades along with the changing life style lead by the people living here, some policy measurements have to be taken to deal the issue in a better manner. Considering those policy options other cities can also adopt some effective measures comparing their situations with that of Delhi. The policy measurements should include economic as well as technical, administrative, social and environmental aspects that will be discussed in the following paragraphs.

Economic Aspects:

Unfortunately, nowhere in India any economic instrument has been applied so far to meet the deficit of funds. Authorities are still charging a flat fee for the municipal services provided to the people. Through this tax structure people can easily escape from the higher tax net even by generating MSW at a higher level, as the fee charged for the municipal services does not depend on the extent of generation. Considering the loopholes present in the existing system, a proper tax structure should be introduced at the municipal level in order to face the problem with upper hand. But the pattern of tax cannot be same for different types of wastes. For example, recyclables like paper, plastics are not heavy that much as their volumes are, where as reverse is true for the organic matter present in the waste generated. So before introducing the tax structure it is more necessary to segregate the generated waste into different parts that will also be helpful in treating the waste.

Segregation of waste: In most of the cities and towns in India the rag pickers and the scavengers segregate waste mainly at the dump-site and collect the useful part like paper, plastics, glass, metals, etc. that have a recycle value in

the market. But the qualities of the recyclable components get reduced by mixing up with other components like earth & inert and also in touch with open environment. As a result major part of those recyclable components remains uncollected by the rag pickers and the scavengers from the pile of waste. So it is necessary, at the household level, to segregate waste so that using the waste for different purposes like recycling, composting, energy generation, etc, would be easier to take place. From the government's side initiatives has to be taken to make the people aware regarding that matter and different waste bins of specified types has to be provided to each household so that they can put their waste properly into the particular waste bins. This type of practice is very common in advanced countries and different coloured waste bins are provided there to the households for different types of waste such as kitchen waste, recyclable waste, hazardous waste, etc. In a city like Delhi same kind of programme has been taken by the authority but, due to unawareness among the people and lack of staff for collecting those wastes, the outcome is not satisfactory. In order to convert this practice into a habit of the people, a mass level awareness programme has to be taken at the household level by both the government and other social organisations.

In performing the activities related to municipal services properly, a group of new staff has to be employed along with the existing workforce. Apart from that eco-friendly waste treatment plant has to set up more in number in all the cities and towns. In order to do so the concerning municipal authorities have to be substantially resourceful to incur the costs associated with that. Since MSW generation significantly depends on gross state domestic product, the above-mentioned activities have to be undertaken by the government to tackle the issue effectively. But presently bulk of the allocated budget is spent on meeting the salary of the employees. Under the circumstances implementing economic instruments is the most effective way out to face the problem of financial adequacy. The economic instruments that can be introduced at the household level and also at the producer's level are unit pricing, recycling subsidy, advance disposal fee, deposit-refund system, etc.

Unit pricing is basically charging fee for per unit of waste generated. Waste like paper and plastic has to be charged on per unit weight basis, as their

volume is quite large compare to their weight. On the other hand, the reverse technique should be followed for the organic part i.e. charging them on the basis of per unit volume as due to the moisture content, this waste is heavy in nature compare to its volume. A separate treatment can be applied for the hazardous part of MSW viz. battery, syringe, tube, paint, machine oil, etc., considering the impact of the substance to the environment. In the presence of this instrument, individuals will think twice before generating more waste, as the fee will vary with the amount generated. This kind of instrument has been proved to be effective in many advanced countries and as a result they have experienced significant reduction in the amount of waste generated.

Recycling subsidy can be another option to the waste generator in which a money back offer is given at the time of depositing a recyclable product after its use otherwise they have to incur higher cost for that. But this option is effective only when the recyclable end use is in a good form and moreover, those things have to be collected at a regular basis. In India, due to the large number of workers associated with the informal sector, collection of recyclable items from door to door is very common everywhere. These workers usually collect paper, plastic, metals, etc. that have recycle value. But these things are mostly common in town areas. In city areas, these workers are not permitted to enter in many housing complexes due to various reasons. There the activity of collecting recyclables from door-to-door fails to operate. The authority should arrange a proper place of collecting recyclables of those areas otherwise this option would not be viable to the common people.

The concept of *advance disposal fee* is effective for the product, which is made from virgin materials. In that case people have to pay more for the product made with fresh elements otherwise they have the option of paying less for the product made with recyclable elements. With this option people have the incentive to incur less cost, hence overall use of recyclables increase. So this particular instrument can be applied for paper products made from fresh pulp or plastics made from fresh elements. Introducing this instrument could reduce use of the products made from fresh raw materials and hence, increase use of the recycled items.

Deposit-refund system is the most accepted economic instrument by the experts. Under this option, an amount is charged as tax at the time of purchase and a refund is also provided if the commodity is given for recycling. Thus this option is, at the same time, effective in reducing waste generation as well as increasing recycling activities. To make an effective implementation of this option, tax rate should be consciously measured so that it would not become a burden to the common people and the amount refunded has to be significant enough to attract the people for depositing the end use for recycling.

Technical Aspects:

Apart from the economic instruments, some technical steps have to be taken by the authority to make better functioning of municipal services. Household should be directed to store the waste at source and discharge it only into the bins provided by the municipal bodies, at specified times. Moreover, they should be provided different types of waste bins to segregate the waste at the place of generation so that restoring of recyclable materials and treating hazardous contents would be easier.

In slum areas, sufficient number of community bins should be provided with suitable sizes and regular collection of those wastes has to be taken place. For the places like hotels & restaurants, markets, hospitals & nursing homes, community halls and construction sites, separate bins should be provided on rental basis to check splitting up of waste from those sources.

In city areas, a recyclable collection point has to be set up in each locality where individuals can deposit their recyclable waste with a money back offer.

Administrative Aspects:

First and foremost, larger amount has to be allocated for this purpose so that sufficient number of staff can be recruited.

With adequate workforce, the process of collection and transportation of waste to the disposal site has to be better off.

Workers should be directed to collect the waste as much as possible and to work even in Sundays and holidays considering the services as emergency one.

In that case the workers should also be provided better salary structure so that they can have the necessary incentives to do those things.

With better budgetary allocation modern vehicles suitable for transporting waste should be purchased in order to minimise the gap between generation and collection of waste.

Mass scale campaigning should be done extensively on a regular basis for generating less waste, segregating them properly, using of recyclable goods, etc.

Extraction of materials for different treatments like recycling, composting, incineration, power generation should be made at the highest extent before land filling. The waste retained should be disposed off in sanitary landfill to avoid the environmental degradation caused by that. Composting should be popularised due to the presence of high moisture content in the waste generated in developing countries.

Social Aspects:

The rag pickers and the scavengers play an important role in MSW management by collecting recyclable elements from households and also from the dumpsites. The amount they are paid for that by the waste dealers is insufficient for them to lead a normal life. Moreover, these groups of people face various health hazards as they come in direct contact with waste and remain exposed off for hours. These workers suffer from skin diseases, respiratory and ophthalmic diseases and from ulcers and infected wounds. Without having any protective instrument they work for hours. No initiative has been taken by the government to include them within organised sector. Moreover, the government discourages them in doing so as it is officially not possible for the government to authorise them. But the role played by the agents of the informal sector can not be neglected and given the present status of inadequate staff, their role should be highlighted by giving them social status through including into organised sector and thus providing them necessary health abating instruments, which can help them in defending various health hazards faced at the work place.

Moreover, a bulk section of the people engaged in this sector, are under aged and they are compelled to do these under extreme financial scarcity. Proper initiatives have to be taken from the government's side to restrict the practice of

engaging child labour in this sector. And that can be possible only through accepting the workers engaged in rag picking and scavenging into organised sector so that they can avail minimum working standard with acceptable salary.

Environmental Aspects:

Even with the increase in recycling activities or reduction in waste generation, a significant amount of wastes remain for further treatment or land filling. Considering the environmental impact, the practice of composting has to be popularised due to the presence of high moisture content in Indian MSW. Moreover, compost matters are very useful as an organic fertiliser thus it plays a significant role in maintaining environmental balance.

Another important as well as environment friendly use of MSW can be in the form of energy generation from it. Municipal solid waste (MSW) is in fact a potential energy source and it is now accepted worldwide that any integrated waste management system should have a 'Waste to Energy' component to maximise environmental protection and economic viability. Generation of energy from MSW has certain distinct advantages such as- (i) The total quality of waste gets reduced substantially; (ii) The quality of leftover waste, from the point of causing environmental degradation, is improved; (iii) Demand for land for disposal of wastes is reduced and carriage cost is reduced as garbage need not be carried to a far away place for dumping; (iv) Proceeds from sale of energy/ products (e.g. pellets) improve the commercial viability of a waste disposal project.

The common routes of production of energy from waste are - (i) Incineration, which reduces the municipal waste approximately 90% by volume and 75% by weight (Sharma, 2001), and (ii) Pyrolysis or gasification, which is a method of thermal decomposition of organic matter under inert atmospheric conditions or in a limited supply of air. Though there is a significant trend in Europe and USA to use city waste incinerators- to generate steam for space heating and /or to produce electricity, incinerating is believed to be unsuitable for municipal solid wastes available in India because the combustion will not be self-sustainable due to high moisture content of wastes of Indian cities. But the gasification

process is very effective and the gas produced (producer gas) can be directly used in Internal Combustion engines (up to about 80% replacement of diesel) or burnt to obtain heat energy. The major advantage of gasification is that a clean gaseous fuel is produced which can be used directly in an internal combustion engine. However, gasification is suitable for waste/ biomass in reasonably dry form, moisture level of below 15%. Pelletisation or Densification is another process of converting waste into a relatively clean solid fuel that can be substituted for kerosene, charcoal or firewood.

To reuse MSW at the maximum extent suitable technology has to be selected depending on the factors like quantity and quality of garbage, climatic conditions (such as temperature, rainfall and humidity), local requirements and life style of the people. Some of the important physicochemical parameters that need to be considered for selection of technology are: size of constituents, density, moisture content, mixed carbon/inert content and calorific value. To have adequate information about these parameters records should be maintained on a regular basis as like aggregate MSW generation level. Otherwise it would be difficult to implement any policy for the management of MSW. Since garbage generated in Indian cities has a very high energy potential, the option of reusing garbage should be carried on considering the benefits derived from it. The government should overcome the related constraints like high establishment costs, technological backwardness, lack of long term strategy and unawareness among the people, etc.

Thus to deal the problem of MSW management the above mentioned steps should taken with prior importance and both individuals and concerning authority should realise the need of those instruments of different aspects for the betterment of the environment.

B. Conclusions:

Throughout this study we have tried to establish the fact that management of municipal solid waste, nowadays, has become an important issue of concern due to its dependence on population growth, changes in life style, rate of urbanisation, etc. Any place with higher population, experiences higher amount of solid waste generation. Similarly, greater amount of MSW generate in a place

with modern life style. For a long time period, developing countries were unaware about the issue of managing MSW as given their socio-economic structure, building up of infrastructural facilities and providing health and education to the maximum people were their primary targets in the process of upgrading their nations. Till date these are the core issues for all the developing countries. But among them, some of have improved their economic condition, like India, to whom issues like MSW management, which basically resembles with western urban life, has become one of the important matters of concern. The problem is more acute for the cities like Delhi, Mumbai, Kolkata, Chennai, Bangalore, etc., where due to the economic, political and social importance; rate of urbanisation is increasing exponentially along with the fact that people living there are gradually adopting the westernised culture that increase consumption of wasteful products. Given these facts, we, in this paper, have made an attempt to assess the problem of municipal solid waste by considering the case of the city Delhi as being the National Capital Territory it has been experiencing a massive rate of urbanisation along with a significant change in the lifestyle of the people living here towards westernised culture.

In doing the analysis, considering the case of Delhi, we have shown that generation of MSW significantly depends on some socio-economic factors like population, per capita income, and public expenditure. As it is obvious that with the increase in the number of people the amount of waste generated will automatically increase. Similarly, people with higher income can afford to purchase more goods in their consumption baskets. Moreover, at a high level of income, people staying in a cosmopolitan city like Delhi, increase their level of spending on packaged goods most of which are luxurious. The current trend of any modern as well as of upcoming city is to opt for the goods that are more attractive in look. Thus attractive packaging of goods has become a fashion in modern society. This trend results in an increase in wasteful consumption. Mainly due to this factor, the proportion of recyclable materials viz. paper, plastic, etc. present in municipal solid waste has increased significantly in case of many growing developing countries. The case of Delhi is also not an exception in this trend. The result, showing the strong dependence of per capita income on the aggregate level of MSW generation of the city Delhi defends this fact

statistically. One of the most important results of our analysis is the dependence of MSW generation on the level of public expenditure related to waste management activities. Our analysis shows an inverse relationship between them. With a higher amount of public expenditure related to waste management activities, the government can play a significant role in the management of MSW by allocating more budgets for municipal services in terms of recruiting more staff, purchasing necessary instruments at sufficient number, setting up of modern waste treatment plant, campaigning for waste minimisation, more use of recyclable products, waste segregation at source, usefulness of compost items, etc. The results derived from the model shows that the government indeed plays a crucial role in the generation of MSW at the aggregate level. Apart from that with a higher per capita income individual can also afford the necessary expenditure for an effective management of MSW provided that they are inspired enough by the restricting activities taken by the government. So the most important step is that government should take adequate measure in order to manage the problem within an affordable limit.

Apart from allocating larger amount of money for public expenditure, the government should introduce economic instruments through the local bodies to finance the necessary costs required for MSW management. As till date, there is no economic instrument has been applied in Indian context, hence effective economic instrument should be imposed in the form of either unit pricing or recycling subsidy or deposit refund system, etc., given the paucity of funds experienced by the municipal bodies.

To end with the discussion of this study one thing has become very clear that without having adequate information regarding the issue and serious initiatives at the individual as well as at the government level the problem will be in a serious form in near future. So effective steps have to be taken by all the concerning agents of this system as early as possible to manage municipal solid waste.

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