SOLID WASTE MANAGEMENT SYSTEM OF CHITTAGONG CITY CORPORATION.

A thesis

by

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Submitted to the Department of Industrial & Production Engineering, Bangldesh University of Engineering & Technology, Dhaka in partial fulfilment of the requirements for the degree of

MASTER IN INDUSTRIAL & PRODUCTION ENGINEERING.

January 11, 1994.

DEPARTMENT OF INDUSTRIAL AND PRODUCTION ENGINEERING.

BANGLADESH UNIVERSITY OF ENGINEERING & TECHNOLOGY, DHAKA.

CERTIFICATE

This is to certify that this work has been done by me and it has not been submitted elsewhere for the award of any degree or diploma.

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ABSTRACT:

Solid waste management is a quite important service activity of the Chittagong City Corporation. To ensure a better performance level determination of optimum number of manpower and equipment facility is a key issue. The individual wardwise allocation is also important because of a wide range of variation both in area and population.

In the present work this allocation is done using fortran computer program. Data on area, population, waste generation rate, capacity of vehicles, disposal site distances from the onsite spot, round trip haul time etc. are used to interact with the different work study data to get the result. This model is developed, taking in mind service maximizing criteria, say a 99% level of performance. The dustbins are allowed to piled up to a height of 1.5 ft. and 2.0 ft. for dry and summer season respectively. But such a service standard is impractical and not economical. Thus the figure is further lowered by multiplying it by a reduction factor to match with the required level of service standard (say 75%). From past few years of operation and maintenance data of conservancy department a smooth graph of level of performance vs. annual cost is established. The very characteristic of the curve is known ahead, this will obviously be a curve of exponential nature. At the extreme up region, above 99% service standard it will be more or less parallel to the abscissa. From this figure the reduction

factor is taken and used in the program to find the final result for the assigned level of performance. The nature of the curve indicates a high reduction factor for a low service standard. The required equipments and manpower are calculated for both the dry and summer season and finally the average figure is represented in the findings.

The present work also studies the main solid waste management issues such as collection, transfer and transport, processing and recovery etc. and try to find out the problems and prospects in Chittagong City Corporation.

This work also presents relevant solid waste management practices in pioneer countries in this South East Asia region to get a overall comparative overview of the present condition of the Chittagong City Corporation.

The author wishes to thank the officers and staffs of Chittagong City Corporation (CCC) specially to Engineer Md. Shamsul Huda Siddikee, Architect Md. Rezaul Karim and conservancy officer Mr. Anil Kanti Basak for sincere co-operation and help in collecting data and relevant information.

Finally his never ending gratitude to his brothers, colleagues and friends who inspired constantly with the best of their prayers and wishes.

ACKNOWLEDGEMENTS:

With deep sincerity, the author acknowledges his profound gratefulness to Md. Golam Mohiuddin, Associate Professor, department of Industrial and Production Engineering (IPE), Bangladesh University of Engineering & Technology (BUET), Dhaka for his kind supervision throughout the course of completion of the thesis work.

His indebtness is due to Dr. A.F.M. Anwarul Haque, Professor and Head of the department of IPE, BUET, for his valuable counsel and deliberate guidance. Also contribution of Professor Dr. Md. Mizanur Rahman (Former head of the dept.) and Assistant Professor Dr. Ruhul Amin Sarker is worthwhile to remember with due respect for their suggestion and inspiration time to time, which helped me to retain the moral spirit for this research work.

The author is also grateful and thankful to Dr. Sultan Ahmed Khan, Associate Professor and the then director in charge of 'Bangladesh Institute of Technology (BIT), Chittagong for his immense help, who also obtained his Ph.D. on Solid Waste Management from IIT, Kharagpur, India in 1991, without which it would have been simply impossible to carry out this work. Also Mr. Mirza Shahnewaz, Associate Professor, Department of Mechanical Engineering, BIT-Chittagong is one of the distinguished to whom I often called on with many problems over the research work.

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CHAPTER I

1.1 INTRODUCTION:

Solid waste management is a multidisciplinary activity. Numerous problems have been associated with solid waste management. It is a dynamic field, so there is no unique or "the best" method for the solution of all the problems associated. In each situation engineering principles must be applied to evaluate equipment and facility options, to make operational choices and to develop management systems. In this way a decision maker can be provided by a proposed best alternative and in terms of cost effectiveness he can choose any of the alternatives. In the developed countries whenever a new system comes due to technological obsolescence or a new one is proposed, its validity and effectiveness is studied and compared with the existing one to grasp the most efficient one. Thus analysis of the present system along with other alternatives are very important to know the potentiality of the existing system.

Today solid waste management is based not only on engineering principles but also on economics, urban and regional planning and social sciences among other fields. Traditional engineering approaches which in the past often neglected public attitudes and concerns are no longer acceptable. Further technological advances has resulted in a change in emphasis in many important areas. Now a days constraints related to public health and safety, economics and environment are of prime considerations. These considerations

should not be over looked.

Chittagong is a very important industrialized city, can be referred just after Dhaka for its potentiality in Bangladesh. It is also a port city, also a city of foreigner gathering for its prospective tourist attraction criteria. Natural hilly layout, healthy climate due to its sea side position, nearby sea beaches make it fascinating to tourists as well as aristocratic dwellers. Thus importance of upgrading the management system of Chittagong City Corporation is envisaging as a vital issue day by day to retain its potentiality.

SWM

As a whole city corporation's activities have a great deal of impact on every aspect for the locality. Also solid waste management is directly related to city dweller's health and hygienic condition as well as overall environment of the of the city. Management authority should have the aforesaid points in mind. But very little or no research work was carried out so far in this area in Bangladesh. Also application of computer programming has not yet been applied in this sector.

The relationship between public health and the storage, collection and disposal is quite clear. Rats, flies and disease vectors breed in open dump sites as well as in poorly constructed or poorly maintained housings in food storage facilities and in many other places where food and harbourage are available for rats and other harmful insects. U.S. Public Health service officials published the results of a study tracing the relationship of 22 human diseases to

improper solid waste management. Eye, nose, throat irritation, bronchitis, dysentery, gastric and jaundice are some examples. Bangladesh lies between $20^0 81'$ and $26^0 38'$ North latitudes and $88^0 81'$ and $92^0 41'$ East longitudes. The summer spreads over about 8 months with a maximum temperature of 40^0c and an average of 27^0c, the rainfall varies from 5000 mm. in the north-east to 2000 mm. in the south-west, which is very favourable for fermentation and leachete generation from solid wastes. In mining areas the liquid leached from waste dumps may contain toxic elements such as copper, arsenic, magnesium, uranium which contaminates water supplies with unwanted salts of those. In the past, liquid from dumps and poorly engineering landfills had contaminated surface and ground water many times. So ecological impacts such as water and air pollution also have been attributed to improper management of solid wastes.

1.2. HISTORICAL BACKGROUNDS AND DEVELOPMENT:

There are four city corporations in Bangladesh with 100 other municipalities. Of them the biggest is Dhaka both in area and population. Dhaka city corporation's present area is 344 sq. km. and has a total population of about 36.5 lakh (7). It was established in 1st August 1864, converted to Municipal Corporation in October 1978 and was upgraded to City Corporation in 1990 (19). Chittagong is the second largest populated urban city. Like Dhaka the history of Chittagong City Corporation is also very old. It first started to function as 'Chittagong Powrasava' in 1st June 1863 and the Chittagong Municipal Corporation was established

in 12th september 1982. Finally it was upgraded to city corporation in 31th July 1990. Its present area is 60 sq. mile and has a total population of 15,66070 as per the population census '91.

Municipal Act was published in 1884 and in that period Magistrate was the chairman of the Paurashava. In 1960 government established the municipal ordinance and later on it was further modified. As per the 1977 Urban Local Body (Powrasava) ordinance, these city corporations and municipalities are responsible for management of solid waste in their community.

1.3. PRESENT SCENARIO AND FRAMEWORK:

With the increased population boom and rapid expansion of city corporation's activities and with the present government's environmental laws, the city corporation is facing many difficulties for solid waste management. Waste disposal has historically been relegated to the lowest level of responsibility in our country. Our country is a developing country, over 80% of our national budget is the assurance of foreign aid. Again most of these aids are associated to categorized development work. So automatically national government's attention substantially goes toward development oriented projects and sectors. The financial condition of city corporation is not favourable to provide efficient solid waste management services. They are to rely on backdated equipment and system and unskilled man power. No specific roadwise route, information network, scheduling, layout has been

developed yet. Present manpower and equipments are also very inadequate. The present organisational structure is shown in chapter-IV, table 4.4. Different staff's and worker's position is also shown in this chart. CCC has 41 wards , total area has been divided into 6 zones for better co-ordination of work. It has a total of 40 vehicles, 20 of them is bound for garbage cleaning. 1 of 285 cft., 4 of 150 cft., 12 of 100 cft., and the remaining 3 is of 60 cft. capacity. More detail is given on discussion of collection system. Here present strength of manpower of conservancy department is given below.

OFFICER:

Designation:	Number
Chief conservancy officer	1
Conservancy officer	1
Subtotal	2

SUPERVISING STAFF:

Designation	Number
Conservancy superintendent	4
Conservancy inspector	21
,, supervisor	35
Mosquito control inspector	16
Squad leader	22
Subtotal	98

CLEANERS/SWEEPERS/CREWS:

Designation	Number
Road cleaner	543
Drain cleaner	188
Refuse cleaner (wheelbarrow man and truck crews)	244
Spray man	117
Insect collector	07
Subtotal	1099
Total	1201

FRAMEWORK:

Chittagong City Corporation (CCC) consists of one mayor, one deputy mayor, 41 elected commissioners and 7 other selected official commissioners. According to the ordinance commissioners are elected through direct voting by adult voters, one from each ward. As per the rules and regulations of the corporation elected commissioners will mandate a mayor and a deputy mayor among them. Mayor and deputy mayor will also be treated as the commissioner of the corporation. Upon discussion with different local bodies of "Women organization" and "Social Welfare organization", government gives selection of women nominee among the potential woman of the city (20). However in the present system mayor is elected by direct voting. The ex-officio commissioners are as follows(20).

1. Chairman, Chittagong Development Authority (CDA).

2. Chairman, Water Supply and Sewerage Authority (WASA).

3. Superintendenting Engineer, Public Health & Engineering Bureau, Chittagong circle.

4. Superintendenting Engineer, Roads & Highway, chittagong.

5. Chief Engineer (distribution), South zone, PDB.

6. Deputy director, Health service department, Chittagong.

7.Chittagong port Authority.

1.4. FUNCTIONS OF CHITTAGONG CITY CORPORATION:

As already stated, duties imposed upon city corporation is vast and multi-dimensional. Other than waste disposal and mosquito control they also have to ascertain proper health service, water supply, sewerage, city planning, road, bridge and culvert construction etc. for the public of the community. They also have to involve in development works, education and cultural activities, social welfare functions and other such programmes. (20)

The existing functions of Chittagong City Corporation may be deposed as below ---

Public Health:

The corporation is responsible for the sanitation of the city, control of environmental pollution and removal of refuse from all public streets, public latrines, urinals, drains, buildings and lands vested in the corporation and for the collection and disposal of such refuse. To keep records of births, deaths and marriage

within the corporation is the task of the corporation. It also adopts preventive measures for infectious diseases by vaccination. Mosquito control scheme is now being executed by the corporation. It also receives a sizable amount of money and equipment donations for projects of different pollution control measures by WHO.

Water Supply and Drainage:

The function of the CCC is to look after, construct, maintain and clean of surface drains only of the city. The water supply and other drainage system, sewerage system has been maintained by WASA.

Articles of Food and Drink:

The corporation prohibits the manufacture, sale or preparation or the exposure for sale of any specified article of food or drink in any place unless licensed by them. The corporation also prohibits the import of such articles for sale without the license. The corporation is authorised for seizure and disposal of any animal, poultry or fish intended for food which is diseased, or any food or drink which is noxious. The corporation has also the function to establish and maintain public markets and secure the proper management and sanitation of such markets.

Culture and Social Welfare:

The corporation provides and maintains public hall and community centres and also provides for the reception of distinguished visitors, arranges any occasional fairs, shows or public festivals within the city. It also maintains burial grounds and ghats.

Trees, Parks and Gardens:

The corporation plants trees on the public streets and public places and takes care for the plantation and protection of trees. It also takes care of different parks and public gardens within the city area.

Engineering Works:

Development and maintenance of roads and sometimes project offered to CCC by Government for viz. bus terminal schemes are the functions of Civil Engineering. Office buildings are also to be constructed by them. Street lighting, street watering and traffic control are the main functions of the Electrical Engineering section. Development and maintenance of road carpeting by asphalt plant, slaughter house, decomposed plants are the Mechanical Engineering functions of the Corporation.

Tax collection:

Corporation collects taxes from the people . Table 1.1 shows different components of revenue of a city corporation.

Table 1.1: Sources of Municipal Revenue in Bangladesh.

Components	Sub-component
Tax revenue:	
Property taxes	a. On annual values of buildings and land. b. Rates on conservancy, water and light. c. Surcharge on urban immovable property tax.
Other taxes	a. On professions, trades and callings. b. Entertainment tax. c. Tolls. d. Minor taxes.
Non-tax revenue: ..	a. Fees and fines, rents and profits from properties, other sources, miscellaneous, earnings etc.
Govt. grant	a. Normal grant. b. Works programme grants.
Deposits ..... and advances	a. Deposits b. Advances.

Source: CUS '90.

1.5. SCOPES AND OBJECTIVES OF THE STUDY:

Scientific and systematic approach applied to problem solving areas and also in planning and management are almost absent in our country, as a result poor performance becomes almost inevitable. In the Chittagong City Corporation it is of no exception. While the city is expanding physically along with population growth a planned service system is necessary.

The objectives of the present research work are set as follows -

i) To study the physical characteristics of Municipal Solid Wastes (MSW) of Chittagong in comparison with other major cities of this region of South East Asia and also study necessary implications arising out of this toward different management issues.

ii) To evolve a model for finding a reasonable figure of manpower and equipments to keep a satisfactory level of performance as economically as possible.

iii) To make necessary recommendations for the overall improvement of the solid waste management system of Chittagong City Corporation.

CHAPTER II

2.1 SOURCES OF SOLID WASTES.

Solid waste comprises all different kinds of solid or semi-solid materials arising from human and animal activities and interactions, that are normally solid and are discarded as useless or unwanted by the possessors. Knowledge of the sources and types of solid waste, the physical and chemical composition of solid waste along with data on characteristics and rate of generation is a basic and must be known for the local authorities to select the most economical collection vehicles, to design and operate efficiently the functional elements associated with the management of solid wastes such as ---

--- to design and operate efficiently a central incineration plant

--- to plan ahead for a suitable landfill sites

--- to design a composting plant or central grinding plant

--- to forecast future demands to be met

--- to project accurately the cost and efficiency of operation to choose a particular method of disposal etc.

Sources of solid wastes are in general related to land use and zoning. Although any number of source classifications can be developed, the following categories have been found useful-

1. Residential
2. Commercial
3. Municipal
4. Industrial

5. Open areas 6. Treatment plants

7. Agricultural 8. Hospitals

Table 2.1: TYPICAL SOLID WASTE GENERATING FACILITIES, ACTIVITIES AND LOCATIONS ASSOCIATED WITH VARIOUS SOURCE CLASSIFICATIONS.

Source	Typical facilities activities, or locations where wastes generated	Types of solid wastes
Residential	Single family and multifamily dwellings, low medium and high rise apartments etc.	Food wastes, rubbish ashes, special wastes, bottles, plastics, packages etc.
Commercial	Stores, restaurants, markets, office buildings, hotels, motels, print shops, auto-repair shops, medical facilities and institutions etc.	Food wastes, rubbish, ashes, demolition and construction wastes, garden trimmings, market sweepings, plastics occasionally hazardous wastes, containers etc.
Industrial	Construction, fabrication, light and heavy manufacturing, refinery, chemical plants, lumbering, mining, power plants, demolition etc.	Food wastes, rubbish, ashes, demolition and construction wastes, special wastes, hazardous wastes. containers
Open areas	Streets, alleys, parks, vacant lots, playgrounds, beaches, highways, recreational areas etc.	rubbish, special wastes, paper boxes, packages etc.
Treatment Plant sites	Water, waste water and industrial treatment processes etc.	Treatment plant wastes principally composed of residual sludge
Agricultural	Field and row crops, orchards, vineyards, dairies, feed lots, farms, etc.	Spoiled food wastes, agricultural wastes, rubbish, hazardous wastes

* Residential and commercial wastes are combinedly known as Municipal wastes, although wastes from some industrial site are also present. Hospital wastes are biologically hazardous wastes such as Phermacuticals, Pesticides etc.

2.2 SOURCES OF MUNICIPAL SOLID WASTES:

Sources of Municipal solid wastes can be fallen to these categories:

1. Domestic refuge:

Refuge that is collected mostly from domestic areas which consists of ash rubbish and garbage.

a. Ash: Ashes and residues are materials remaining from the burning of wood, coal, coke and other combustible wastes in homes, stores,institutions and some industrial and municipal facilities for the purposes of heating, cooking and disposing of combustible wastes. Residues from power plants normally are not included in this category. Ashes and residues are normally composed of fine powdery materials, cinders, clinkers and small amount of burned and partially burned materials.

b. Rubbish: Rubbish consists of combustible and noncombustible solid wastes of households excluding food or other putrescible wastes. Some rubbish may also arise from institutions and commercial activities.

i) Combustible rubbish: It consists of materials such as paper, cardboard, plastics, textiles, rubber, leather, wood, furniture and garden trimmings.

ii) Noncombustible rubbish: It consists of items such as glass, bottles, crockery, tin cans, aluminium cans, ferrous and other non-ferrous metals, dust and dirt.

c. Garbage: It is also called as food wastes. Food wastes are the animal, fruit or vegetable residues resulting from the handling, preparation, cooking and other consumption of foods. The most

important characteristics of these kinds of waste is that they are highly bio-degradable specially in warm sultry weather. It continues fermentation on storage. The waste food, vegetable peelings and other organic matter should be removed as soon as possible.

In addition to food wastes a considerable amounts of garbage is also generated at cafeterias and restaurants, large institutional facilities such as hostels, hospitals,prisons and facilities associated with the marketing of foods including wholesale and retail stores and markets.

2. Street refuse:

Refuse that is collected by the street cleaning service or scavenging is called street refuse. It consists of leaf, straw, paper, animal droppings and litter of all kinds.It is also grouped into three categories-------

a. Natural wastes: These include dust blown from other area, decaying vegetation such as leaves, blossoms and seeds. These wastes can not be avoided but may be controlled.

b. Road traffic wastes: Motor vehicle deposit oil, mud, animal excreta, construction materials etc. These wastes can be avoided through legislative measures.

c. Behavioural wastes: Litter thrown by the pedestrians, wastes swept or thrown out from house, shop, market etc., excreta of domestic animals etc. These wastes can be avoided by continuous public education and legislation.

3. Market refuse:

Refuse that is collected from market is called market refuse. It consists of large varieties of putrescribles such as vegetables waste, dry vegetables and leaves and animal matters like remains from butcher's shop and others.

4. Industrial refuse:

Refuse that is collected from industrial area within the city municipality is called industrial refuse. It comprises wide varieties of wastes ranging from completely inert materials such as calcium carbonate to highly toxic and explosive compounds.

5. Demolition and construction wastes:

Wastes from razed buildings and other structures are of this category. Wastes from the construction, remodelling and repairing of individual residences, commercial buildings and other structures are classified as construction wastes.

6. Hazardous wastes:

Chemical, biological, flammable, explosive or radio-active wastes that pose a substantial danger immediately or over time to human, plant or animal life are classified as hazardous wastes.

2.3 CLASSIFICATION OF SOLID WASTES:

It is important to note that like composition the definition and classification of solid wastes vary greatly in the literatures. No generally accepted data for composition of refuse is available and

various authoritative sources and knowledgeable experts studies derive analogous but different discrete data. A common reason is that the samples and analytic techniques for examination of refuse vary and are not standardised.

Different organizations classified solid wastes in a somehow different view to facilitate their own objectives. Here most common of them is discussed in table 2.2.

Table 2.2: Refuse Categories, Content and Sources from Incinerator Institute of America Standards.

Type	Description
0	Trash: a mixture of highly combustible waste such as paper cardboard, wood boxes, and combustible floor sweepings, from commercial and industrial activities. The mixture contains up to 10 percent by weight of plastic bags, coated paper, laminated paper, treated corrugated cardboard, oily rags, and plastic or rubber scraps.
1	Rubbish: a mixture of combustible wastes such as paper, cardboard, cartons, wood scrap, foliage and combustible floor sweepings, from domestic, commercial and industrial activities. The mixture contains up to 20 percent by weight of restaurant or cafeteria waste, but contains little or no treated papers, plastic or rubber wastes.
2	Refuse: containing of an approximately even mixture of rubbish and garbage mixture by weight. This type of waste is common to apartment and residential occupancy, consisting of up to 50 percent moisture.
3	Garbage: consisting of animal and vegetable wastes from restaurants, cafeterias, hotels, hospitals, markets and little installations.
4	Human and animal remains: consisting of carcasses, organs and solid organic wastes from hospitals, laboratories, of up to 85 percent moisture.
5	By product waste: gaseous, liquid or semi-liquid such as tar, paints, solvents, sludge, fumes etc. from industrial operation.
6	Solid by product waste: such as rubber, plastics, wood wastes etc. from industrial operation.

Solid wastes may also be classified as based partly on content and partly on moisture and heating value. This is a more generalized one. A typical of this classification is as follows -

a) Garbage: Refers to the putrescible solid waste constituents produced during the preparation storage or eating of meat, fruit, vegetables etc. These wastes have a moisture content of about 70 percent and a heating value of around 6×10^6 J / Kg.

b) Rubbish: Refers to the non-putrescible solid waste constituents either combustible or non-combustible. Combustible rubbish has a moisture content of around 25 percent and a heating value of about 15×10^6 J / Kg. Non-combustible wastes are metals, glasses, ceramics etc.

c) Pathological wastes: This is dead animal, human wastes etc. These wastes have a high moisture content of about 85 percent. There are 5% non-combustible solids. The heating value is around 2.5×10^6 J / Kg.

d) Industrial wastes: Solid wastes arising from Industrial processes and manufacturing operations are classified as industrial wastes. Chemicals, paints, sand, metal ore processing, fly ash, sewage treatment sludge etc. are industrial wastes. These wastes have wide varieties and such characterization is not attributable to it.

e) Agricultural wastes: Farm animal manure, slurs, cereal, cereal

straw, crop residues etc. are of this category.

f) Special wastes: Hazardous wastes, explosives, bulky wastes such as abandoned vehicle or vehicle parts, tires, furniture, trees, branches, large appliances like refrigerator, etc. radio active materials, security wastes,confidential documents, negotiable papers etc. are special wastes.

2.4 MUNICIPAL SOLID WASTES (MSW):

It is already defined Municipal Solid Waste (MSW) is a combination of Residential and Commercial solid wastes.

The analysis of MSW to know the physical and chemical composition, trends, likely variability and other such characteristics is very important and should be known for the municipal authority. These information have a great value in evaluating alternative equipment needs, systems, management programs and plans.

If the solid wastes generated at a commercial facility consists of only paper products the use of special processing equipment such as shredders and balers may be appropriate. Separate collection may also be considered if the collection agency is involved in a paper products recycling program. The unwanted matters such as oil, water, dirty sweepings mixes readily with paper and increases the cost of recycling and degrades the quality of the recycled product. Specially separating unwanted synthetic, oil, fat and other such heavy substances needs a very expensive recycling process of

procedures. Thus if the management can sure of large amount of paper content it can consider separate collection, if the management feels it feasible and economical.

Evaluation of the feasibility of incineration plant depends largely on the chemical composition of the solid wastes. So only a information about chemical composition can provide a unique management decision.

A large organic content indicates the necessity for frequent collection and removal.

Plastic in high concentration indicates possible problems in their disposal.

Composting which involves the biological stabilization of solid matter either under aerobic or anaerobic conditions, can also be concluded as yes or no by only chemical analysis. The nitrogen, phosphorus and potassium content of the waste represent the fertilizing elements and a high value of these element represents favourable composting.

The following analysis of Dhaka city refuse (7) discloses some decision points for Municipalities in Bangladesh.

Table 2.3: ANALYSIS OF DHAKA CITY REFUSE.

Constituent (%)	Domestic Refuse	Market Refuse
Moisture content	45.3	53.6
Fixed residue	57.2	55.6
C	22.6	25.7
P	0.05	0.36
N	0.41	0.36

The above analysis indicates the followings ---

a. high moisture content

b. low phosphorus content.

c. high ash content.

On a careful consideration of the above characteristics it is felt that incineration of the waste will not be viable as --

1. A large amount of heat will be needed to evaporate moisture contained in the waste.
2. Plastic and paper which mainly add to the calorific value are also found in a low proportion.
3. Ash and inorganic content is high.

A self sustained combustion reaction can not be attained for the above characteristics and hence incineration will become prohibitively costly and can not be recommended.

The low value of N, P and K represent that compost will have low nutrient containing fertilizer and large bulk compared to chemical

fertilizer. So composting can also be concluded as no. Therefore sanitary land filling can be recommended as the appropriate option for disposal of solid wastes in Bangladesh. Under the assistance of WDB and ADB provision for de-mountation container which disposes wastes directly from the on-site location) and sanitary land filling is going to be adopted for municipalities of Bangladesh very soon. (Daily Ittefaque ,Economics page, 2nd Feb. 1993)

Whether management can go for commercial recycling economically is also can be found readily from physical compositional data of MSW. The decision criteria is also negative following the low percentage of valuable inorganic substances such as glass, aluminium, ferrous, other non-ferrous metals and reusable organic contents such as plastic, cardboard, paper, rubber, leather etc. Waste's physical composition also represents different category of equivalent fuel value. Now a days the equivalent fuel value methodology is being used to compare recycling to recover material values at a mass burn waste to energy (WTE) plant and a refuse derived fuel (RDF) WTE plant, both generating electrical power. It was determined that the equivalent fuel value, under conditions that exists in Pinellas County Florida during the Middle East crises reached $ 57.41 /ton of as-received MSW. There is a saving of about 1.15 to 1.35 barrels of No. 2 fuel oil/ton of MSW when the waste is used to generate electric power (13). Various environmental impacts that can result from collection, shipping and the lost energy opportunity values appeared to exceed the environmental benefits of recycling the material values of

combustible MSW components. However more will be discussed on recycling in time. In Dhaka and Chittagong recycling is going on by some private organization in small scale.

There has also a great relation between physical data and standard of living. It may be stated that the higher the income level, the higher the paper content of the refuse and lower the income level, the lower the food waste content of the refuse. The per capita waste generation in USA is much more higher than the value in ASIA due to higher standard of living. Not only total quantity but energy values both from recycling and mass burn is also higher in developed countries.

Different tables of local and international refuse analysis will assist developing expanded idea about characteristics of MSW and are discussed in the following articles.

2.5. COMPOSITION AND CHARACTERISTICS OF MSW.

The refuse characteristics depend on a number of factors such as food habit, cultural tradition, standard of living, level of technological advancement, socio-economic and climatic condition etc. Following these factors characteristics vary not only from country to country, town to town, community to community but also time to time. with growing technological enhancement packaged food products is gradually leading to more food wastes in agricultural and processing plants than in residential areas. On the other hand

bins of these areas is getting rich in cans, aluminium foils, empty tins, plastics and other packaged materials. It is observed that at the end of december a huge amount of paper waste is gathered in the dustbins of western countries following the X-mass ceremony. These discrete information should be known to the municipal authorities. Sometimes characteristics vary even within the city itself and of course seasonally.

Wastes have three main characteristics:

-----weighed generated

-----density

-----and constituents.

Table 2.4: International variation in refuse composition (21)

(on percent dry basis)

Components	U.K	Asian City	Middle East City	USA
Vegetables	30.6	75.0	50.0	20.0
Paper	31.2	2.0	16.0	43.0
Metals	5.3	0.1	5.0	7.0
Glass	3.8	0.2	2.0	9.0
Textiles	4.1	3.0	3.0	3.0
Plastics	5.2	1.0	1.0	5.0
Others	19.8	12.7	23.0	13.0
Wt./person /day	0.845 Kg.	0.415 Kg.	1.06 Kg.	1.946 Kg.

Some important points to note from the above table are ---

(i) high paper content of American refuse and correspondingly low vegetable content compared to other countries. (ii) The high

vegetable content of Asian refuse and intermediate composition of Middle Eastern refuse. Thus it must be emphasised that experience and observed trend in one country can be quite different from those of another. As already defined failure to recognise these facts may have disastrous consequences in planning an efficient management system. In order to design an efficient high temperature incineration plant or composting plant, detail information of the physical characteristics, chemical and biological characteristics of refuse analysis is required together with the likely variability.

Table 2.5: Comparative Refuse Analysis of South East Asia.

	Bangkok	Bangalore	Bangalore	Hongkong	Jakarta	Seoul	Taiwan	Chitta gong
Analysis Source	Municip ality	*	NEERI Summer	**	**	**	**	Home survey
Vegetable/Putrescible	44.0	75.2	65.1	9.42	60.0	_	24.6	70.0
Paper	24.6	1.5	2.7	32.46	2.0	4.0	7.5	6.0
Metals	1.0	0.1	0.4	2.17	2.0	0.4	1.1	2.0
Glass	1.0	0.2	0.2	9.72	2.0	0.15	2.8	0.5
Textiles	3.0	3.1	0.9	9.58	_	_	3.7	1.0
Plastic & Rubber	7.0	0.9	0.0	6.24	2.0	1.8	2.3	1.5
Misc. combustible	_	0.2	0.2	4.94	7.0 [1]	0.6 [2]	-	
Misc. incombustible	3.5	6.9	1.2	_	_	78.0 [3]	56.0 [3]	
Inert below 10 mm.	4.8	12.0	_	14.09	_	_	-	21.0
Fine Earth.	_	_	29.0	_	_	_	-	
Other materials	_	_	_	10.47	25.0	13.7	0.8	
Density (Kg./ m^3)	250	570	405	_	_	_	-	_

*. Analysis by Flintoff Burner, WHO consultant. **. Country reports on solid wastes management seminar, Bangkok 25-30 sept. '78.
1. egg shells 2. wood 3. ashes

Physical composition of solid waste of Chittagong City Corporation: (At disposal site) (Appendix -1)

Category	% in wt. basis
Vegetables / Putrescribles	28.4
Paper	0.5
Metals	2.1
Glass, Ceramics, Rubber, Polythene, Leather	3.5
Textiles	1.0
Wood, Brick, Stones etc. building materials	7.7
Drainage, sweepings and other unidentified	57.0

Table 2.6: Typical physical composition (% by wt.) of MSW of Chittagong City Corporation and density (31).

	PhySical composition	
Component	Range	Typical
Food waste	35-80	70.0
Paper	1-8	6.0
Plastic	0-2	0.5
Polythene	0.5-3	1.0
Textiles	0-3	1.0
Glass	0.4-1	0.5
Garden trimmings	0-5	2.0
Wood	0-4	1.5
Glass	1-4	2
Tin cans	0-3	1.0
Ferrous metals	0-10	1.0
Dirt, ashes, brick etc.	0-10	6
Others	1-10	9.5

2.5.1. SOURCE DENSITY CUM ON TRUCK DENSITY:

Density of Municipal solid wastes as delivered in compaction vehicles have been found to vary from 600 - 1000 kg /m^3. A typical value is 750 kg /m^3 . This density is on an average. Density varies from source to source in a wide range. Table 2.7 shows the variation of density for different sources of Dhaka City Corporation. As the wastes are loaded into the truck from pick up points the density increases but not as much as stated above, because compaction vehicles are not used.

Table 2.7 discloses that though compaction has not been done a remarkable amount of density is increased here. The % of compaction is 8.5 - 30 %.

Table 2.7: Comparison of source density and on truck density (3).

Collection Area	Source density (kg/m^3)	On-truck density (kg/m^3)	% of compaction
1. Court House St.	665.0	752.0	13.0
2. B.C.C Road	717.0	815.0	13.6
3. Mouluvibazar	670.0	720.0	7.5
4. Dhanmondi	461.0	500.0	8.5

result indicates that waste of source 1 and 2 have a higher density. This is most likely due to street and market sweepings containing a large amount of sand, dust, mud and other heavy substances.

2.5.2. CHEMICAL ANALYSIS OF MSW:

Information on the chemical composition of solid wastes is important in evaluating alternative processing and recovery options. To determine the fuel value of MSW four most important properties to be known are --

1. Proximate analysis:

a. Moisture (loss at 105^0c to 1 hour.)

b. Volatile matter (additional loss on ignition at 950^0c)

c. Ash (residue after burning)

d. Fixed carbon (remainder)

2.Fusing point of ash:

3.Ultimate analysis:

Percent of C (carbon), Hydrogen (H), Oxygen (O), Nitrogen (N), Sulphur (S) and ash.

4. Heating value:

Table 2.8: Typical Proximate analysis of the combustible components of MSW (6).

	value (%)	
Components	Range	Typical
Moisture	15-40	20
Volatile matter	40-60	53
Fixed carbon	5-12	7
Glass, metal, ash	15-30	20

Typically solid wastes can be thought as a combination of semi-moist combustible and non-combustible substances. Thus the mixture is a complex one and requires a great deal of attention and effort in deriving their characteristics by different physical and Chemical analysis. Different analysis for MSW performed by the developed countries are as follows ----

Physical analysis: Physical analyses have so far been performed include weight, volume, bulk density and separation of waste into component categories.

Chemical analysis: Chemical analyses include moisture content (really a physical parameter but usually performed as part of chemical investigations), volatile solid content, ash residue, gross calorific value, sulphur content, phosphorus content, nitrogen content, carbon content, hydrogen content etc.

Biological analysis: Biological analyses include Coliform, Streptococcus, Beta-haemolytic, Fungi and Pathogenic Staphytococci. Discussion about these is out of our horizon.

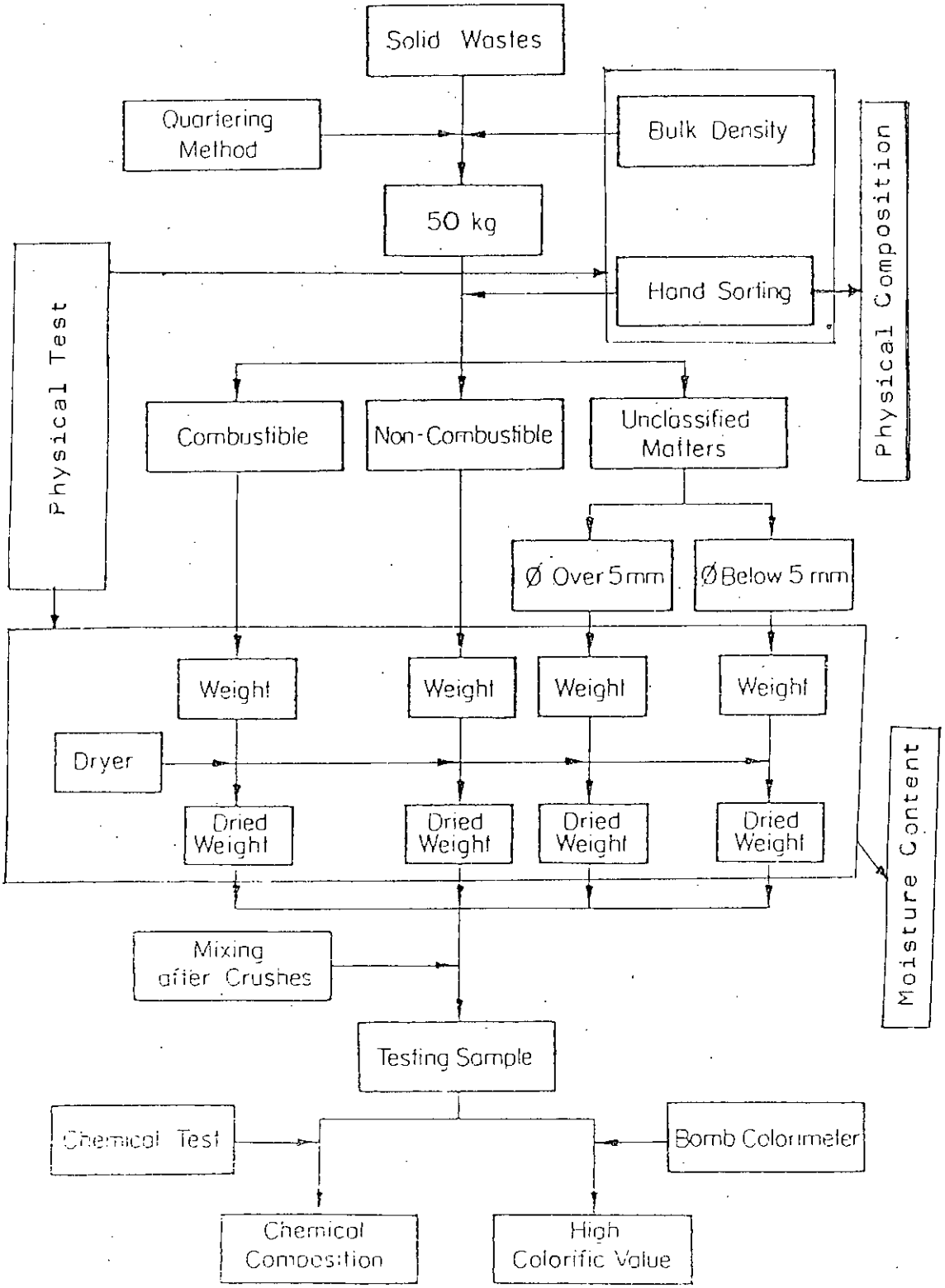
A flow chart for guidance to different analyses is shown below.

Table 2.9: A comparative data of chemical characteristics of MSW available in different countries is given below (21).

CHARACTERISTICS OF MSW

Characteristics	Indian City	USA	West Germany
Moisture	31.18	20.30	-
Organic matter	27.57	30.35	16.30
C	15.32	25.30	-
N	0.58	0.6	0.1
P as P_2O_5	0.59	-	0.1
K as K_2O	0.67	-	0.4
C/N	26.23	48.50	-
HCV (Kcal/kg.)	1140	3330	2775

Guidance of Characteristics Analysis



Instruments and Methods of Analysis

Element	Pretreatment	Quantitative Analysis	Instrument
Carbon	Combustion ($C \rightarrow CO_2$) adsorption 800°C	Gravimetric analysis	Elemental Analyzer
Hydrogen	Combustion ($H \rightarrow H_2O$) adsorption 800°C	Gravimetric analysis	Elemental Analyzer
Nitrogen	Kjeldahl digestion ($N \rightarrow NH_3$), then distillation	Volumetric analysis (Neutralization)	Elemental Analyzer
Sulfur	Combustion ($S \rightarrow SO_2$, SO_3) absorption	Volumetric analysis (Neutralization)	Elemental Analyzer
Chlorine	Combustion ($Cl \rightarrow Cl_2$; HCl) absorption	Volumetric analysis (Volhard method)	
Oxygen	(Ignition Loss) − (Carbon) + (Hydrogen) + (Nitrogen) + (Sulfur) + (Chlorine)		
Organics	Ignition loss at 800°C	Gravimetric analysis	Electric furnace
Phosphorous	Acid digestion	Colorimetric analysis (Molybdenum Blue Method)	Colorimeter of Spectro photometer
pH	Dissolved in Water (1:5)	Electrometry	pH meter with glass electrode
Calorie			Bomb calorie meter
Moisture Content		Gravimetric analysis	

Note Detail procedure can be obtained from the following paper:

S. Muttamara (1979) Analysis of Refuse. Proceedings of the 2nd Regional Seminar on Solid Waste Management, December 3, 1979, Bangkok, Thailand

CHAPTER III

3.1. WASTE GENERATION A CONSEQUENCE OF LIFE:

Problems with the disposal of solid wastes can be traced from the time when human first began to congregate in tribes, villages and communities. In early times the disposal of waste did not pose much problem as the population was small and the land available was large. With the advent of industrialization and urbanization the problem of waste disposal increased and the accumulation of waste became a serious consequence of life. Littering of food and other solid wastes in medieval towns, the practice of throwing wastes into the unpaved streets, roadways and vacant land led to the breeding of rats with their attendant fleas carrying the germs of disease caused the outbreak of pleague and other subsequent epidemics. The high death tolls in the 14th. century which was mainly caused by this disease was continued and terminated almost half of the Europeans until the 19th century. In 19th century public health control measures became a vital consideration to the 'Public Health Service' officials. They began to realize that food wastes had to be collected and disposed off in a sanitary manner to control the vector of disease.

Thus while the capacity of nature to dilute, disperse, degrade, absorb or otherwise dispose of its unwanted residues in the

atmosphere, in the waterways and on the land is well known, unwanted residues arising from consequences of human life should be controlled or otherwise an ecological imbalance will be imposed on the biosphere of our country, especially when our MSW mostly originates in residential areas containing large percent of putrescible substances, which is highly degradable and decomposes rapidly in summer season.

The medieval practices of throwing and littering here and there still in effect with remarkable intensity in cities of Bangladesh. This is a major eye-sore in urban dwellers daily life. In our country the problem is more acute and has been leading to adverse impact on the environment day by day. The acuteness of the problem may be attributed to some major social problems as discussed in a brief in the following sub-chapter.

3.2. SOCIAL INTROGATION INTO THE PROBLEM.

There are so many problems in this domain related to socio-economic conditions of our country. Some of the major factors are discussed here with some illustrative statistical data to get a overall out look of the acuteness of the problem.

1. High population density and growth rate: Though the growth rate is lowered from 2.53 to 2.220 (simple) for population census ,81 and ,91 but the figure still transcends more than 80% countries growth rate around the world. Chittagong stands just after Dhaka in

Population density serial. The average number of occupancy per unit is also increasing rapidly. Report reveals that from 1966 to 1973 average occupancy per unit increases from 5.0 to 6.4 for Chittagong City. This value was found to increase from 5.5 to 7.7 for Dhaka City. Table 3.1 shows different components of population growth of major cities.

Table 3.1: Components of population growth in major cities of Bangladesh (22).

	Components		
Cities	Natural increase	Immigr-ation	Annex-ation
Dhaka	18	74	8
Chittagong	28	43	21
Khulna	27	73	-
Rajshahi	30	36	34

2. High level of urbanization: The level of urbanization of different cities of Bangladesh is shown in Map-2. The following tables will assist in realizing the trend of urbanization. It will also delineate present condition and position of our urbanization level worldwide.

Table 3.2: Urbanization trend of Bangladesh, 1951-2015 (23).

Year	Total Popu. (lakh)	Urban Popu.	Rural Popu.	Growth rate of Urban Popu.(%)	% of Urban Popu. to total
1951	419	17	402	2.7	4.1
1961	545	21	524	2.1	3.8
1974	764	68	696	9.5	8.9
1981	900	135	765	10.3	15.1
1985	1006	175	831	6.5	17.4
1990	1137	229	908	5.4	20.1
1995	1206	294	974	5.0	23.2
2000	1411	373	1038	4.8	26.4
2005	1550	404	1094	4.4	29.8
2010	1705	508	1137	4.0	33.3
2015	1846	679	1167	3.6	6.8

Table 3.3: % of Urban population and growth rate (World wide) (30)

Country	1950		1980		2000	
	*	**	*	**	*	**
Africa	1.6	14.8	7.9	28.8	19.0	42.3
Latin America	9.7	41.2	27.3	64.7	37.5	75.1
East Asia	4.6	16.7	12.1	32.7	19.1	45.1
South Asia	2.6	15.9	7.4	24.8	14.5	37.1

*. % of population living in cities with 1m. or more inhabitants.

**. % of population living in urban areas.

Map 1

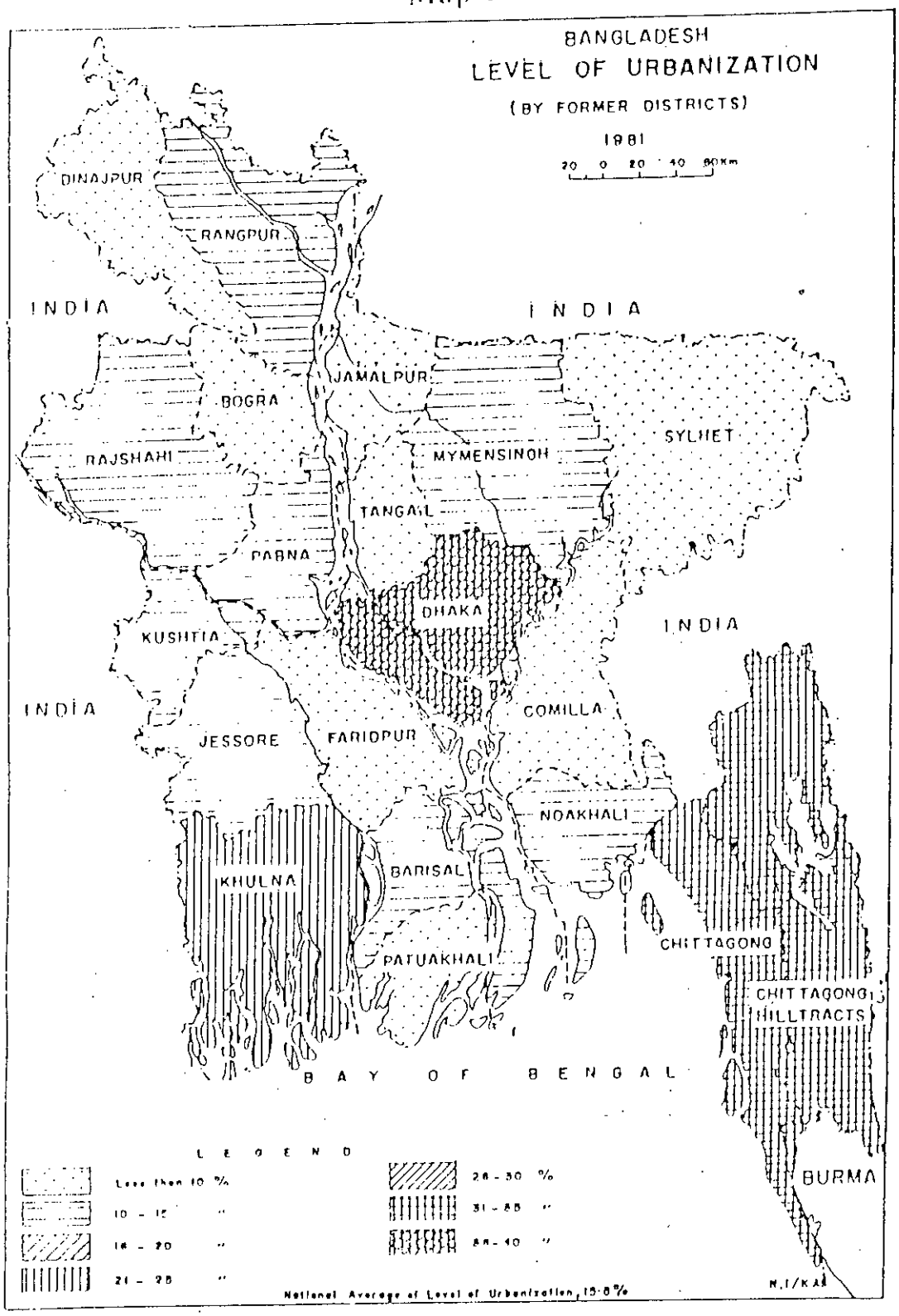

BANGLADESH
LEVEL OF URBANIZATION
(BY FORMER DISTRICTS)
1981
20 0 20 40 60Km
DINAJPUR
RANGPUR
INDIA
INDIA
JAMALPUR
BOGRA
SYLHET
RAJSHAHI
MYMENSINGH
TANGAIL
PABNA
DHAKA
INDIA
KUSHTIA
INDIA
COMILLA
JESSORE
FARIDPUR
NOAKHALI
KHULNA
BARISAL
CHITTAGONG
PATUAKHALI
CHITTAGONG HILLTRACTS
BAY OF BENGAL
BURMA
LEGEND
Less than 10 %
10 - 15 "
16 - 20 "
21 - 25 "
26 - 30 %
31 - 35 "
36 - 40 "
National Average of Level of Urbanization, 15·8%
N.I/KAB

Table 3.4: Level of urbanization by Division and Dist. (24).

Name	Level of urbanization: Division *	Division **	District ***
Dhaka	15.35	39.7	38.9
Chittagong	15.43	25.7	32.2
Khulna	14.40	18.2	22.5
Rajshahi	10.40	16.2	10.8
Bangladesh	15.35	100.0	

*. Urban population in % of total population of the Division.
**. Urban population in % of total national population.
***. Urban population in % of total District population.

3. Intensive land use for residential, commercial and industrial activities:

Table 3.5 shows the demand trend of residential housings for a year gap of two decade.

Table 3.5: Demand of new housings in urban centres.

	1980		2000		
Area	Popu. (lakh)	Housings (lakh)	Popu. (lakh)	Housings (lakh)	Required Housings
Dhaka	35.0	5.1	93.0	16.91	11.81
Chittagong	14.0	2.2	40.0	7.27	5.07
Khulna	7.0	1.08	23.0	4.18	3.10
*	6.0	1.21	35.0	6.36	5.15
**	10.0	1.58	37.0	6.72	5.14
***	45.4	6.98	163.0	29.63	22.65
Total	118.0	19.0	391.0	71.09	52.87

*. Other towns having a population over 1 lakh.
**. Towns having a population over 50 thousand.
***. Others Source: WBB Urban sector memorendum'81.

4. Trend of rural illiterate people to move to urban areas and to congregate on slums and squatters: Now a days the sprawling slums and informal settlements throughout the city in the developing countries is a big obstacle to proper implementation of city plan. So city plan should be accompanied by different rehabilitation program for this section. Table 3.6 shows the percent of slum dwellers to the total City dwellers of Dhaka.

Table 3.6: % of slum dwellers of different cities of the world.

City	Year	Urban (%) growth	Slum Dwellers (%)
Dhaka	'75	10.0	50.0
Collombo	,,	1.2	25.0
Lahore	,,	5.4	40.0
Karachi	,,	5.6	23.0
Osaka	,,	2.0	1.0
Delhi	,,	5.7	30.0
Islamabad	,,	6.5	40.0
Bogota	,,	6.2	60.0

Source: UNO-HUMAN DIVISION REPORT '74-'82

People of these slums are in a very deplorable standard of living. The municipal and other community facilities are very low to these areas. Table 3.8 discloses a survey report of Dhaka City on different municipal and other facilities got by them. These areas are increasingly causing adverse impact to city environment day by day. Table 3.7 shows some environmental consequences of these slums in Dhaka City.

Table 3.7: Distribution of different elements which influence the environment to different slums.

	% of 1125 slum nos.
Waste disposal system	..... 8.6
Good water drainage system	..... 34.8
Kancha narrow road	..... 31.3
Herring bonded road (less than 4 ft. wide)	..... 7.5
Herring bonded road (greater than 4 ft. wide)	..... 1.8
Pucca road	..... 8.1
Free from flood	..... 34.2

Source: SUS 1988, Slums and Squatters in Dhaka City '88

Table 3.8: Distribution of different slums according to Municipal and Community facilities got by them.

Facilities	No. of slums	% of 1125 slums
Gas	341	30.3
Electricity	627	5.7
Water supply (WASA)	563	50.0
Bath place	575	51.1
Tube-well	164	14.6
Public lavatory	974	86.6
Mosque	116	10.3
Primary school	64	5.7
Open place	115	10.2
Grossery shops	296	26.3
Health complex	38	3.4

Source: as above

A survey on the occupation structure of slum dwellers may help in implementation of rehabilitation program and is given in table 3.9.

Table 3.9: Occupational structure of slum dwellers of Chittagong and Khulna City.

Occupation	Madarbari slum Chittagong (25) Total no.:1249	Boalkhali slum area, Khulna (26) Total no.:1124
Transport labour	5.2	3.4
Day-labourer	8.0	23.8
Factory worker	-	2.1
Carpenter	-	0.8
Masonry worker	-	0.4
Motor mechanic	_	0.5
Hawker	15.1	2.5
Bearer	9.0	0.5
Tailor	-	4.2
House wife	19.5	34.4
Servant	2.6	-
Small scale traders	3.8	11.2
Quack	-	0.2
Cottage industry worker(Knitting)	20.7	-
Fisher man	13.5	1.0
Beggar	1.5	7.6
Others	1.1	7.4
Total	100.0	100.0

Children of different slums are mainly related to unauthorised reclaiming activities of solid wastes. They collect these wastes from on-site storage bins and open dump areas. A survey report for Dhaka City discloses that 23% of child labours are related to

reclaimable waste collection (has been named as Tokai) with an average per day income of taka 17/-.

5. Poverty, illiteracy and public ignorance: Other than slum areas the overall condition is also poor. A survey on real GDP of former Districts in '85-'86 reveals that the value for Chittagong is 1254.6 and the lowest 735.7 is for Rajshahi District. In chittagong city 37.5% houses are kancha and 27.3% houses are half-pucca. The highest percent of kancha houses is found in Dhaka city, 38.2% (survey report '82). Literacy rate for Chittagong City Corporation is 43.67% (BBS,population census '91.). Motivation and law and regulation exercise can improve the public ignorance and unawareness.

3.3. SOLID WASTE GENERATION IN BANGLADESH:

According to '91 survey report conducted by delegates from both Dhaka city corporation and Chittagong city corporation, during summer season the total quantity of wastes collected per day for Dhaka City Corporation (DCC) is 713 tonne and 537 tonne during summer and dry season respectively.

Thus, per capita waste generated /day at the disposal site is

= (713x 1000)/ 3637892 = 0.2 kg/cap./day.

In Chittagong City Corporation (CCC) this amount is observed to vary from 300-350 tonne/day during summer season. Thus waste generation rate at the disposal site is = (300x1000)/1566070

=0.2 kg/cap/day.

This low generation rate at disposal site is due to unauthorised recycling and disposed off at the community mostly in unhygienic way to barren lands, nearby ditches, canals etc. In Chittagong the Chaktai khal has been being used for these kinds of foul practices. The river Karnafuli is also being polluted by municipal and industrial wastes. The actual generation rate will be higher. Recently it is said that DCC generates a daily waste of 700-800 tonne in dry season and 900-1100 tonne during summer season which gives a generation rate of 0.3 kg /cap./day. (27)

Twenty families of different standard of living of Chittagong City Corporation were selected and solid waste production over seven days during summer seasosn was observed. It is found that domestic solid waste generation rate is about 0.29 kg./cap./day. Including other commercial and industrial waste, 20% extra (6) we have ------

Waste generation /cap /day = 0.29 X 1.2 = 0.34 kg./cap./day.

In our present study per capita waste generation for dry period is taken as 0.25 kg. and for summer period it is taken as 0.34 kg. Usually seasonal variation causes a 30-35% increase in total waste stream. According to WHO consultant Flintoff Burners report, the average percapita waste generation for Dhaka and Chittagong City Corporation is 0.35 and 0.28 respectively. This figure for collection rate is 0.305 and 0.25 respectively.

3.4. WASTE GENERATION OF OTHER COUNTRIES:

It is already stated that the primary source of refuse generation is domestic. A recent study of solid wastes problems in New York City showed that 51.7% MSW originate in residential area, 38% from commercial sources and the remaining 10.3% from industry. About $20x10^6$ kg. of household refuse were produced in Federal Republic of Germany in 1975, 90% of them was dumped, 9% was burnt and 15 was composted. On an average 4.4 billion tonnes of solid waste is generated each year in USA alone. Of this approximately 230 million tonnes represents MSW, 140 million tonnes industrial wastes, 640 million tonnes agricultural wastes. The greatest amount of solid waste comes from mines and mineral and from animal wastes each with an average of 1.7 billion tonnes per year (6). Every year they are disposing 1.6 billion unused pen, 2.0 million razor and blade, 220 million tyre and 16 billion one time used towels. (27)

During '74s, for just the Municipal and Industrial refuse the generation rate in USA is approximately 3600 lb/cap./Yr. Other industrialised countries have comparatively lower rates, but their estimates may be treated as rough, not much meticulous as USA. Japan is closest to USA with an average of 800 lb., in West germany it is about 500 lb., in Netherland over 600 lb. (6). Every year requirement of a new disposal site is being felt. In USA 80% wastes are landfilled to 6000 different low lying vacant lands. 3000 of these have already been filled up through past five years. Since '93 another 2000 of these selected lands is expected to be dumped. In West Germany 35-50 thousand selected areas have been filled

up so far. These areas has been declared as dangerous for underground water pumping because of their leachete contaminating the underground water. If this continues, either the rate of consumption will be lowered or more serious effort will be made to recover and reuse the wastes (27).

In Asia, Hongkong with a population of only 57 lakh disposes 10. 0 tonnes of only plastic wastes daily which is three times than that of London (27). According to recent survey report it is observed that per capita daily solid waste output is 0.5 kg. in Bombay and Calcutta and 0.3 kg in Punae and Nagpure in India. Daily Municipal collection is 800 metric tonne. In the three cities of Andhra pradesh, the capita values are more or less equal and ranged between 0.17 - 0.2 kg/cap./day (11). In Hydrabad which is a large city in the same state, due to its cosmopolitan nature and higher standard of living, the per capita value is 0.33. The per capita contribution for different Indian Cities may be ranged from 0.15-0.42 kg/day. Fig 3.1 represents a comparative data on solid waste generation rate for different countries.

3.5. GENERATION TRENDS:

In terms of solid wastes management planning knowledge of future changes in the composition of solid waste is very important. Future trends must be assessed carefully, especially in long term planning. For example if a paper recycling program is instituted on the basis of current distribution data and if paper production will

be eliminated in the future, such a program would be more than likely and will become a costly "White Elephant" in the long run.

It was observed in the united states that the quantity of residential food wastes collected has changed significantly over the years as a technological advances and changes in public attitude. Two technological advances that had have a significant effect are the use of the home grinder and the development of the food processing and packaging industry. But now a days a trend is bring developed towards the use of more raw rather than processed vegetables following the environmental awareness of people and because the effects of inflation have become more widespread.

The percent increase in the quantity of paper produced in the United States amounts to more than twice the percent increase in population for the years 1950 to 1962. This tremendous increasing slope represents a clear indication of continuation of further increase in future trend. Past trends in generation thus also make future forecast easier. Studies of per capita waste generation over a 10 year period indicated an annual increase of about 2% in Philadelphia and Des Moines.

The graphical representation and analysis of observed data can be used to depict and evaluate trends and to determine the reliability of conclusions made from a limited set of observations. Time series, histogram or frequency plots and frequency-probability plots are used extensively for the presentation and analysis of data and comment on future forecast and trend. In forecasting the future amount of solid waste generation, rate of population increase should also be considered.

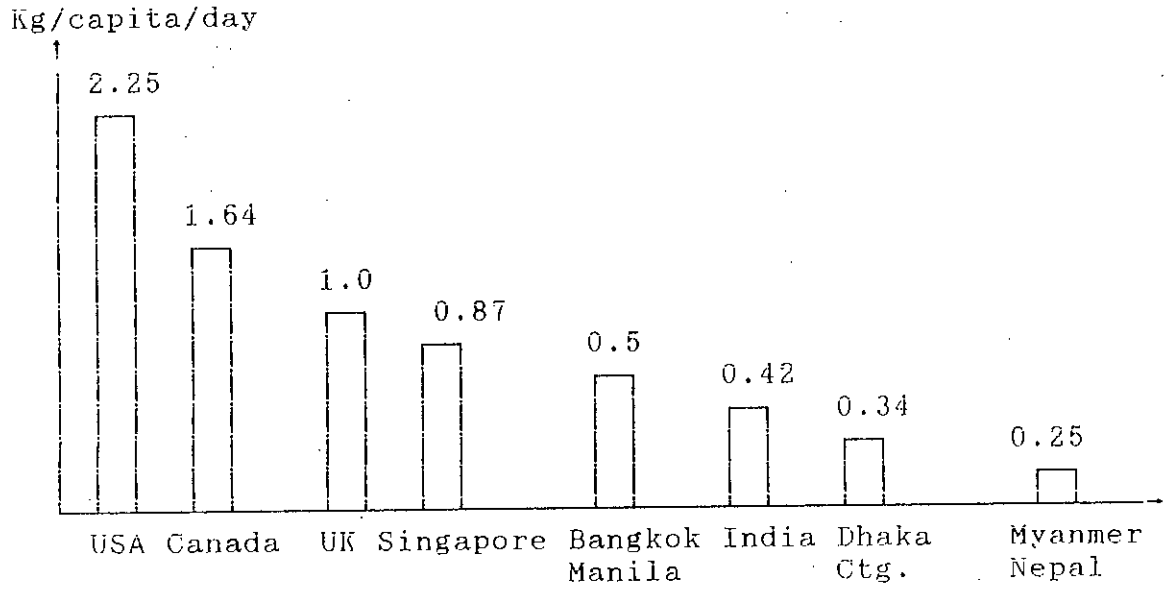


Fig.3.1: Avg. per capita solid waste generation rate in different countries(12,28)

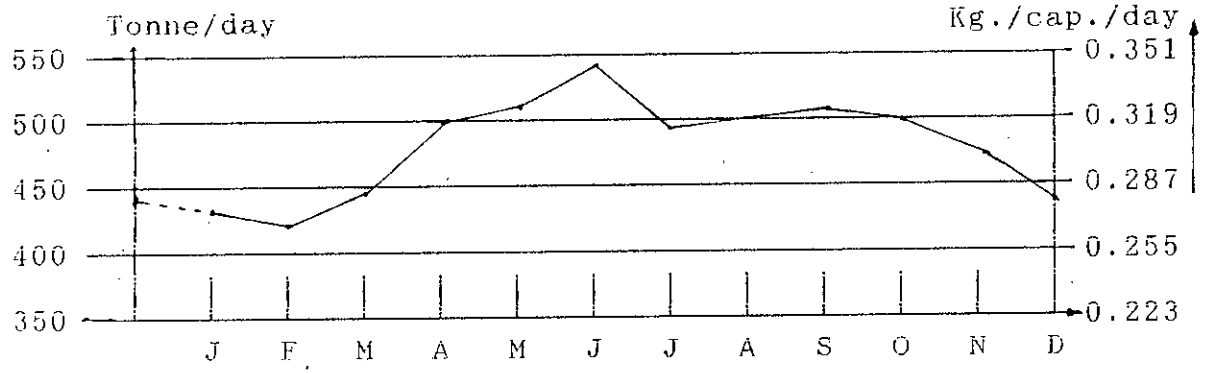


Figure 3.2: Seasonal variation in combined waste stream.

3.5.1. SEASONAL VARIATION:

Seasonal variation adds a new dimension to the generation trend. The quantity of certain types of solid waste are affected by the season of the year. For example, the quantity of food wastes are affected by the growing season for vegetables and fruits. Following figure 3.2 shows seasonal variations in waste generation.

In Wisconsion, refuse generation is at its minimum level in January and February and at its maximum in June and July. These seasonal trend is more or less same all over the world. In Dhaka survey report (3) reveals that during summer season waste generation is at its maximum, 713 tonne and at its minimum, 573 tonne during winter. Studies of waste composition in Chicago showed that during winter there is a decrease in the percent of yard food, glass and metal wastes and an increase in percent paper products, textiles, plastics, rubber, leather, rocks and ashes.

3.6. FACTORS AFFECTING GENERATION RATE:

a) Geographic location: Different climatic condition of different geographic location can influence both the amount of certain types of solid wastes generated and the collection operation. For example in the warmer southern part of USA, where the growing season is considerably larger than in the northern part, yard wastes are collected not only in considerably greater amount but also over a longer period of time.

b) Season of the year: As described earlier the quantity of certain types of solid wastes are also affected by the season of the year.

c) Frequency of collection: In general it has been observed that where unlimited collection service is provided, more wastes are collected. It does not mean that more wastes are generated. For

example if a home-owner is limited to one or two containers per week, he or she may stores news papers or other materials in the garage or storage area, because of limited container capacity. With unlimited service the home-owner tend to throw them away.

d) Characteristics of population: Characteristics of population influence the quantity of waste generated. It is observed that the quantity of yard wastes generated on per capita basis are considerably greater in many of the affluent neighbourhoods than in other parts of the municipality.

e) Extent of salvage and recycling: The existence of salvage and recycling operations within a community affects the quantity of wastes collected. Whether such operations tend to change the generation is yet to be determined.

f) Legislation: A important factor affecting the generation of certain types of wastes is the existence of local and/or govt. legislations concerning the use and disposal of specific materials. Legislation dealing with packaging and beverage container materials in USA is an example.

g) Public attitudes: Significant reduction in the quantity of solid wastes may occur when and if people are willing to change on their own volition their habits and life styles to conserve national resources and to reduce the economic burdens associated with the management of solid wastes.

3.7. CALCULATION OF WASTE GENERATION RATE:

The subject of solid waste generation rate caused considerable confusion because of the different methods of measurement and the waste classifications adopted for reporting data. Therefore in many solid waste management study, extreme care must be exercised in allocating funds and deciding what actually needs to be known. Methods generally used to asses the per capita generation of solid waste are -----

1. A load-count analysis.
2. Weight-volume analysis.
3. Materials balance analysis.
4. Stratified random sampling.

It is customary to note that the estimation of residential and commercial waste generation rate seldom reflect the exact true figure because of so many confounding factors, such as on-site storage and types, the use of alternative disposal locations, uncontrolled wastes which are thrown away indiscriminately, that make the true rate difficult to obtain. In most cases the generation rate is actually the rate of generation at disposal site i,e. collection rate. The actual generation rate is considered somehow greater. The amount of increment is solely dependant on constraints related to the specific community.

1. Load-count analysis: Here the unit generation rate is measured as: (average loads collected/day) X (average volume/load) X density.

2. Weight-volume analysis: Here vehicle weighting is performed using a weight bridge. The weight of waste load is found by deducting the empty vehicle weight from it. The volume of each type of vehicle is measured by tape-measurement. This detailed weight-volume data obtained by weighting and measuring each load over a specified period of time gives more accurate result. It provides better information on the density of various forms of solid wastes at different locations. This type of data for DCC is shown in table 2.7. Sometimes this method is performed on an average basis for an easy approximation as ----

The average load found by sample weighting

X total no. of loads/day.

3. Materials balance analysis: The only way to determine the generation and movement of solid wastes with any degree of reliability is to perform a detailed materials balance analysis for each generation source.

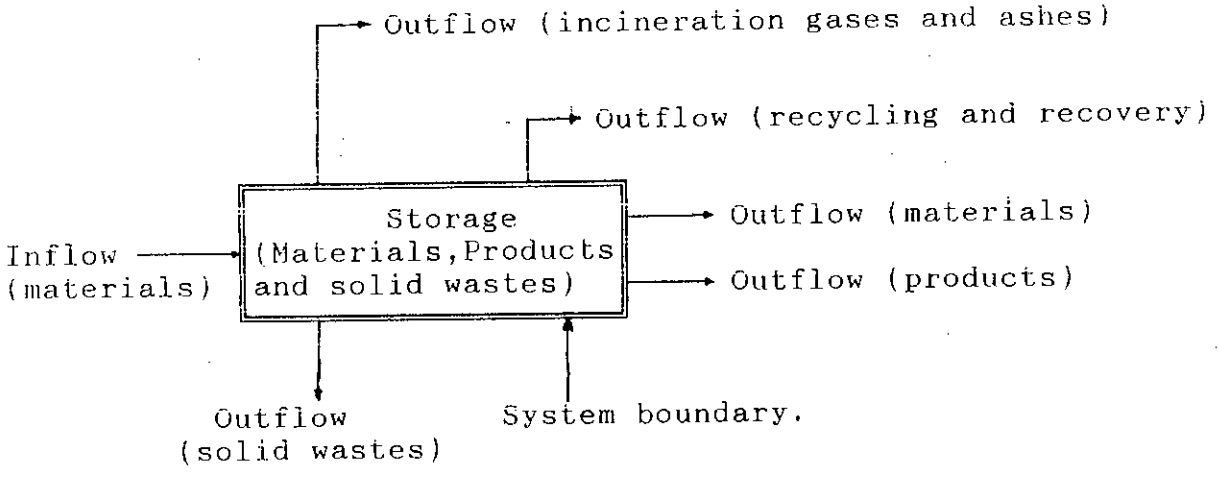


Figure 3.3: Materials balance definition sketch.

Because of the high expense and large amount of work involved, this method is used in special situations only.

4. Stratified random sampling: The process of dividing the whole population into a number of socio-economic groups, the minimum of which is three such as high, medium and low income level is called stratification. The groups are so that elements within each group are alike. Some kinds of sample is selected from each group for this purpose. The sample is called a stratified sample. The group from which the sample is drawn is called strata. This kind of sampling is used to get greater sampling accuracy.

Three main criteria is used to determine the strata.

a) Total population.

b) No. of housing units classified by condition.

c) Average value (market value) for owner occupied units.

Finally estimation of the total city refuse is obtained by simple extrapolation of the sample data on a weighted basis for each of the socio-economic strata. The per capita is found dividing it by the total population. This estimate then may be checked periodically against the known total quantity of refuse generated.

At least 400 people should be sampled for this method. Let population of low, medium and high income level strata are x, y and z respectively, then corresponding sample numbers would be $400x/(x+y+z)$, $400y/(x+y+z)$ and $400z/(x+y+z)$ respectively

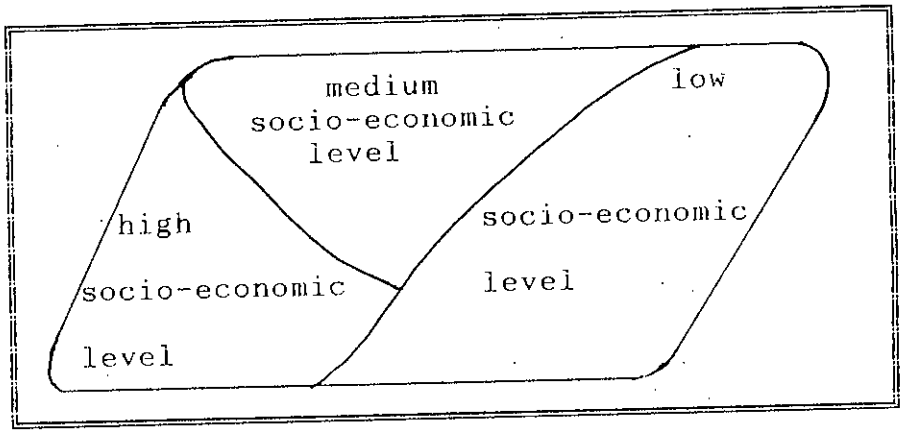


Fig. 3.4: Typical categories according to socio economic level.

Selection of sample tracts or locations is done here as representative of the whole level, by placing major emphasis on the similarity of family income and owner occupied house value.

Many cities in Asia do not follow this method because of the difficulty in dividing the population into socio-economic groups.

CHAPTER IV

4.1. SOLID WASTE MANAGEMENT SYSTEM:

Solid waste management should be accomplished in an efficient and orderly manner. Thus the fundamental aspects and relationships involved must be identified and understood clearly. The activities associated with SWM from the point of generation to final disposal may be grouped into six functional elements as illustrated in the simple flow chart in figure 4.1.

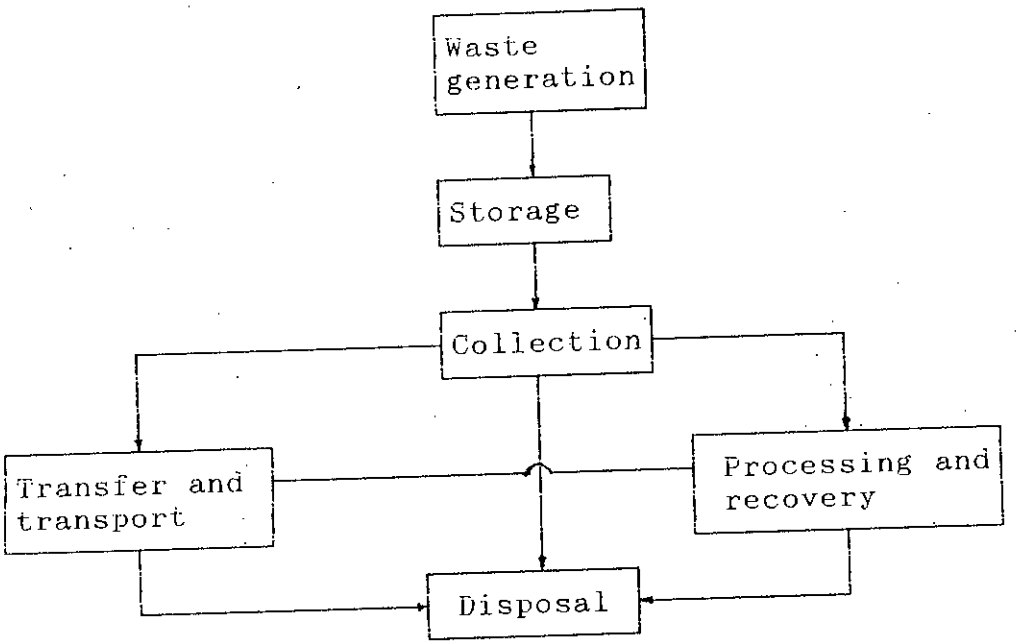


Figure 4.1: Flow diagram representing the six basic functional elements of solid waste management system.

Although solid waste management also include financing, operations, equipment management, personnel, reporting, cost accounting, budgeting, administration, public communication etc., our discussion

will only cover these six elements with special reference to collection and transportation.

4.2. WASTE GENERATION:

Waste generation encompasses those activities in which materials are identified as no longer being of value and are either thrown away or gathered together for disposal. Waste generation arises from production, preparation of goods and/or use and consumption of goods and services. From the standpoint of economics, the best place to sort waste materials for recovery purposes is at the source of generation. Our homeowners are more aware of the importance of separating newspapers, Aluminium or steel cans, bottles etc.In Germany, three separate pipe lines are fitted to every kitchen of multi-storied buildings to facilitate housewives to discard waste categorywise. Three pipes are used for metallic, non-metallic and putrescible materials respectively.

4.3. ONSITE STORAGE:

'The cost of providing storage for solid waste at the source is normally borne by the householder or apartment owner. It is most likely in case of block collection. In our country communal collection operation is followed where housewives gather waste in basket or polythene bag and dispose time to time to the near by dustbins.

4.4. COLLECTION:

Collection involves not only direct loading of wastes from bins situated at curbside, roadside to the vehicle bound for the disposal site but also collection of wastes from narrow streets and alleys by handcarts, vans etc. to hoard it up to roadside fixed bins. In case of block collection it also involves collection of wastes from the household and community storage and emptying the container into the vehicle. In Asia,Collection by street sweeping and drain cleaning is manual except in very few countries like Singapore. The type of brooms used is usually of coconut fibre or of fine bamboo tendril which varies from short, flexible, hard brushes to stiff brooms with long handle.

4.5. DIFFERENT COLLECTION SYSTEMS:

1. Communal storage:

Which may require delivery of the wastes by the householder over a considerable distance to a fixed place. It is most likely of our city municipalities. In most countries of Asia this is also being practised. The organization of solid waste collection system is greatly simplified by the use of communal storage sites. For communal storage specific locations are imposed at which householders deposit their wastes. Thus these sites are a nuisance to the people who live adjacent to them. Frequently wastes are thrown around them, wastes are burrowed by birds, dogs, cattle, scavengers searching for saleable materials encouraging breeding of

flies and other rodent vectors, which furthermore aggravates the problem in our country. In this collection system collection service may vary from three times a week to twice daily.

The commonly used communal storage are as follows ---

PERMANENT:

a) Fixed storage bins: Usually built from concrete blocks. Capacity is around 2 cu. m. In Chittagong City Corporation avail sizes of this type are ------

Old big size : 7 ft. X 3 ft. 8 inch. X 4 ft.

Old small size : 3 ft. X 3 ft. X 2 ft. 6 inch.

but now old sizes are no longer followed. When it is necessary to repair or construct a bin new standard is being adopted. Formulation of the program is based on the new sizes. The available new sizes are ------

base area:

New big bin : 9 ft. X 4 ft.

New medium bin : 6 ft. X 4 ft.

New small bin : 4 ft. X 4 ft.

Flap covering the opening of bin is rarely observed in CCC.

b) Concrete pipe sections: Usually is used for low density population areas. The most common size is of around one meter diameter. The size used in Chittagong have a perimeter of 8 ft. and 3 ft. height. These bins occasionally may also be moved with great

exertion. These are accessible to insects and animals and requires great deal of effort to lug out wastes.

c) Depots: It consists of a single storied building about the size of large garage and is usually used in the densely populated area. Capacity is up to 25 m^3. It has concrete floors and brick walls. Wastes are protected from rain and other adverse weather by some shading. It requires initial high cost and acquiring site for depot. Use of basket for waste removal is a must and workers are exposed to regular skin contact with wastes which may cause health risk. These are the shortcomings of this type. In CCC this type is not in use.

PORTABLE:

a) Drums: Drums are most widely used for its lightness and cheap nature. The drums can be carried with wastes and can be directly emptied in the transport vehicle. Thus the loading becomes faster. A big drum would have a capacity of around 200 litre. There are some demerits also. They are deliberately or accidentally overturned by unauthorised persons and animals. Causes scattering of waste due to small opening. Often sharp corners cause injury to workers and the very cause that they are often lost by miscreants and thieves.

b) Portable steel bins: These bins are made of steels and plastics and have a capacity of 70 - 100 litres. This can be fitted with lids. Hygienic storage and efficient collection of wastes can be performed by these bins properly. But it requires a significant

initial expenditure and high standard human behaviour. These bins are heavy and usually needs two man to empty. It is also frequently lost by thieves.

c) Enclosures: These are usually built from timber, corrugated sheet, brick or concrete. They usually sited on a road side verge or at boundary of an open space. The capacity usually varies from 1 to 10 cu. m. These enclosures are sometimes made dirty by urination and defaecation by some stupids.

Due to heavy loss through burglary practise of portable bins are strongly discouraged by municipal authority.

In CCC handcarts (Wheelbarrows) are used to gather wastes from inaccessible narrow roadside bins. Cane baskets are also used to load street sweepings and drain cleanings to the vehicle and also to load wastes from fixed bins. No animal carts are used. The size is as follows -----

Wheelbarrow size: Length = 2 ft. 10 inch.
Breadth = 1 ft. 11 inch.
Height = 9.5 inch.

Cane basket size: Face diameter = 1 ft. 4 inch.
Height = 11 inch.
Highest perimeter = 4 ft. 4 inch. (it is observed 2 inch. below the top.)

2. Block collection:

Where householders deliver waste to the vehicle at the time of collection. A regular route and prescribed time interval is properly maintained in this system.

3. House to house collection:

a. *Curbside collection:* Where householders put out the bins and later retrieve it.

b. *Door to door collection:* Where the collectors enter the premises and householders are not involved in the collection process.

This collection system is very rare.

TRANSFER STATION: Other than these, transfer station type collection system is also used where the city area is vast and the disposal sites are far away from the generation source. Resource recovery stations may also be treated as transfer stations. When two or more transfer stations and idsposal sites are available, optimum allocation of wastes to these sations and sites are performed by trade off analysis among some factor of preferences as stated below. The analysis method is known as transportation model based on hauling costs and haul distance matrices.

Whenever possible transfer stations should be located -----

i) as near as possible to the weighted centre of the indivisual solid waste production areas to be served.

ii) within easy access to major arterial highway routes as well as near secondary or supplemental means of transportation.

iii) where there will be a minimum public and enviromental objection to the transfer operations and

iv) where construction and operation will be most economical.

4.6. TRANSFER AND TRANSPORT:

The functional element transfer and transport involves two steps i) the transfer of wastes from the smaller collection vehicles to the larger transport equipments and ii) the subsequent transfer of wastes usually over long distances to the disposal sites. In CCC no intermediate collection vehicles such as animal carts, motor tri-cycle are used. Again no trucks are used to deposit wastes to large trucks or tailors. Thus the transportation time or round trip time may be considered as the three discrete segments.

i) Time needed to load a truck.

ii) Time needed to reach to the disposal site after loading and come back to the route location again.

iii) Time needed to unload the truck.

There are total 20 trucks in CCC for disposing wastes. The vehicle details are presented in table 4.1.

Table 4.1: Data on vehicle type and capacity of CCC.

Designation	Capacity cu. ft.	Total number	No.of Truck crew
Old vehicle (big)	285	1	5
Old vehicle (small)	150	4	5
New vehicle (big)	100	12	4
New vehicle (small)	60	3	3
Total		20	

4.7. PROCESSING AND RECOVERY:

Recycling to reduce the volume of MSW by resource recovery is a economic waste minimization approach. It may reduce up to 25-40 percent of waste stream. According to EPA report, USA produces 150 million tons of garbage a year. 90% of these are landfilled, 5% is incinerated and remainder is recycled (21). Different wastes are recycled for different purposes: paper for pulping, metal, glass for remelting, rubber, plastic for downgraded use etc.

There is very little scope for recycling to be embodied in the corporation activities as a planned stage. The following discussion will disclose some causes.

Now a days recycled paper products are extensively used for very high price of "Mondo" and worldwide scarcity of raw materials. A survey report reveals that USA, Taiwan, South Korea and Japan uses

9243, 4012, 1139 and 616 thousand metric tonnes of waste paper respectively for the year 1987. This figure is 150 and 80 for India and Thailand respectively. Recently downgraded recycled papers are used for tissue paper making. In Bangladesh the per capita consumption of paper is very low, slightly greater than one kg. This amount is three kg for India and Pakistan. During past two decade consumption of paper has increased to a great extent in almost every country but not in Bangladesh. Not only paper the other reclaimable materials present in wastes are also very low for very poor consumption. The cause can be ascribed to high population density, low percent of literacy level and poverty or lower standard of living (9). In this region Bangkok's refuse is characterized for its high paper content about 25-32 percent. Bangalore wastes with only 2% paper, Seoul 4% and Taiwan 7% are most typical of this region as a whole.

The consumption of metal, glass, plastic is also very low in Bangladesh. On the other hand extraction of reusable and resalable wastes at the generation source is very strong due to poverty. This kind of sorting by the homeowners makes the recycling of negligible value. The application made by the homeowners are as follows.

i) Fragments of coal, cow dung, coconut shells etc for fuel use.

ii) Metal cans for use as a domestic pot and vessel.

iii) Vegetables waste for animal feeding.

iv) Newspaper, Metallic scraps, plastics, bottles for selling to hawkers.

At every stage of collection and disposal saleable items are also being extracted by rag-pickers, scavengers and tokaies. As already

stated following a slum survey report that a child-labourer earns Tk. 17/- daily by this kind of extraction work. So waste becomes valueless when it finally reaches to the disposal site (25). However a optimistic report for possible market value of reclaimable materials of Chittagong City Corporation is given below in table 4.2.

Table 4.2: Market value of reclaimable materials of MSW of Chg.

Materials	% out of 500 tonnes /day	Amount of materials tonnes	Price per kg. of materials	Total price (taka)
1. Paper	6.0	30.0	2.0	60,000
2. Polythene	1.0	5.0	3.0	15,000
3. Plastic	0.5	2.5	-	25,000
Hard plastic			16.0	
Soft plastics			14.0 } 10	
PVC/ hard pipe			30.0	
Sponge			2.0	
4. Glass	0.5	2.5	3.0	75,000
5. Steel	1.0	5.0	7.0	35,000

Total = 1,42,500/-

But other than recoverable materials found from sorting, our solid waste have prospects of recycling energy values. We know that around 70% of our MSW is organic in nature which is highly degradable and produces leachate in presence of moisture. Under controlled environment feeding this leachate into anaerobic filter or digester, growth of methagenic bacteria to produce bio-gas can be accelerated to a great deal of extent. One kg. of solid waste

can produce 8.25 litres of leachate of COD (Chemical oxigeen demand) value 6000 mg./l, which may produce 8.25 X 3.3 = 27.5 litres of bio-gas.

Thus amount of bio-gas that can be produced from solid wastes of Chittagong City Corporation is -----

= Amount of biodegradable wastes X 27.5 litres/day

= 0.7 X 500 tonnes/day X 1000 X 27.5 litres/day

= 9625 $m^{3/day.}$

Thus the corporation authority can opted for installation of a biogas plant effectively.

4.8. DISPOSAL:

Disposal is the ultimate fate of all solid wastes. Engineering principles must be followed to confine waste to the smallest possible area, to cover them to reduce exposure to vermin. Recently mechanical volume reduction unit is being used. These high pressure compaction systems has been used to reduce landfill requirements and to produce materials suitable for various alternatives.

About 90% wastes in Asia is disposed by crude dumping, although sanitary landfilling or controlled tripping is being practised to some extent in Korea, Singapore, Taiwan and Hongkong. Here some outstanding methods of waste disposal is being discussed in brief.

4.8.1. INCINERATION:

Here combustible wastes are reduced to ash by high temperature

burning for getting fuel value from the MSW. Relatively a small site is required to set incineration plant but on the other hand, the capital cost for installation and operational cost is relatively high. It also arouses the question of extended air pollution.

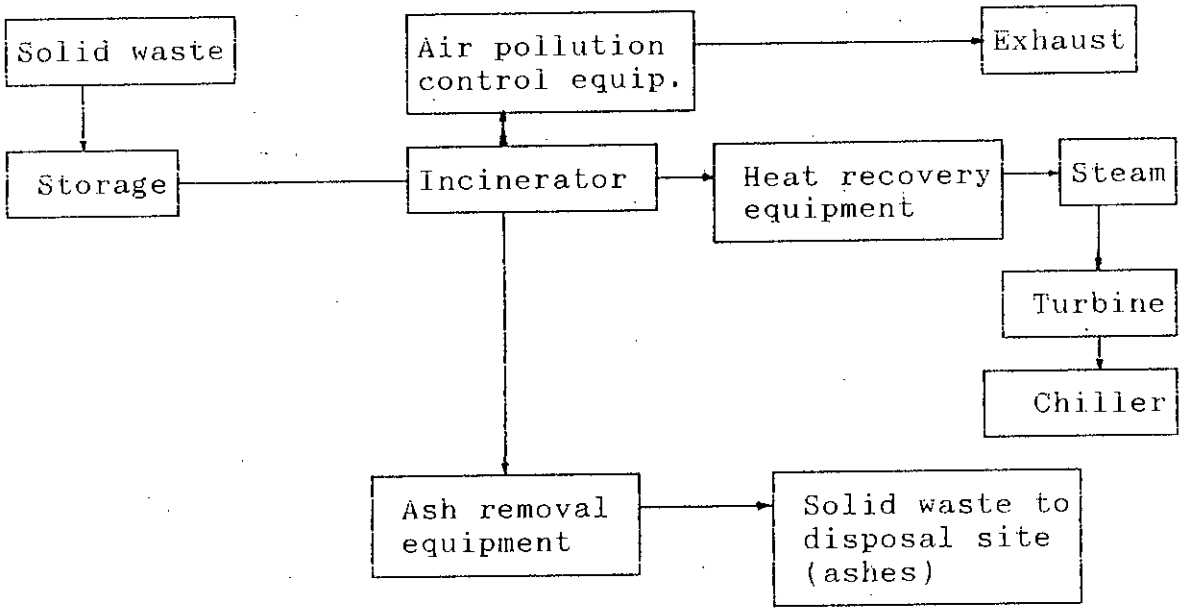


Figure 4.2: Flow chart for the Nashville thermal transfer corporation energy conversion facility, USA (6).

Following wastes are usually advocated for incineration.

i) Biologically hazardous wastes such as hospital or pharmaceutical wastes, pesticides wastes etc.

ii) Wastes which are resistant to bio-degradation and persistent in the environment such as plastic, rubber and latex wastes.

iii) Liquid wastes which are highly volatile and therefore may easily be disseminated.

iv) Liquid wastes having a flash point below 40^0 c.

v) Wastes which contains organically bounded halogens, lead,

mercury, cadmium, zinc, nitrogen, phosphorous and sulphur.

vi) Solvent wastes, waste oils, oil emulsion, oil mixtures.

vii) wastes which cannot be disposed in a several landfill sites.

Up to 1979 there were 522 incineration plants in operation worldwide (21). Recently Japan is using incineration to produce heat for warming residential houses and swimming pool water. They also operate a large green house project by this (ref. Ittefaque, 02.02.93.).

However practice of incineration is very low in Asia. Few incinerator operate in the region in a very limited extent. An incinerator is being operated in Sri- Lanka mainly for destruction of foodstuff condemned as unfit for human consumption and disposal of animal carcasses. A small incinerator plant in the Philippines is at present non-operational due to its high operating cost (14).

4.8.2. COMPOSTING:

Composting is sometimes defined as rapid but partial decomposition of moist, solid organic matter primarily garbage by the use of aerobic organisms under controlled conditions. The result is a sanitary nuisance free, humuslike material that can be used as a soil conditioner and fertilizer. Theoretically the advantages are several, the end product is valuable and should result in revenue for a city, the site for the plant is small and hauling organisms are destroyed if the refuse composted is turned periodically so

that all positions of it come to high temperature zone at some time. The process of composting involves an interaction between the organic wastes, micro-organisms, moisture and oxygen. The end product compost is made of the more resistant residues of the organic matter, break down products, dead and some living micro-organisms togetherwith products from further chemical reaction between these materials.

Non-mechanized or manual composting is successfully operated in India but is rare elsewhere in Asia. In Taiwan the provincial Govt. have erected semi-mechanical refuse compacting treatment plants. A mechanized composting plant is also being operated in Bangkok. All these are not commercially successful because much of the products remained unsold. (14).

Composting is specially suitable and being widely adopted recently for desert countries as a soil conditioner. Here composting materials are spread as a thick layer under the ground to a depth of 0.5 to 1 ft. This enables the soil to retain water effectively. As already stated composting will not also viable for Bangladesh.

4.8.3. SANITARY LANDFILLING:

The American Society of Civil Engineers has defined it as a method of disposing solid wastes on land without creating nuisances or hazards to public health or safety by utilizing the principles of engineering to confine the refuse to the smallest practical area, reducing it to the smallest practical volume and covering it with

a layer of earth at the conclusion of each days operation or at such more frequent intervals as may be necessary.

It has been ruled that domestic refuse is to be disposed in a series of layers, each layer not exceeding 6 ft.(1.8 m.) in depth and that all surfaces exposed to the air is to be covered over 9 inch. (0.2 m.) of earth within 24 hour of the refuse being disposed. This practice was designed to minimize ----
i) landfill fires ii) nuisance from vermin, birds and flies
iii) windblown litter iv) obnoxious odour.

Hazardous wastes cannot be disposed in a landfill in their original or chemical state. As a general rule wastes have to be stabilized prior to disposal in a landfill site. Sufficient care should be given to the chemical interaction between wastes when more than one type of wastes are landfilled at the same location. The waste is spread and compacted in thin layers within a small area. This layered structure is known as cell having a thickness not over 2 meter.The cell is then covered with a layer of soil normally a thickness above 20 cm. When final desired elevation is reached a final covering of soil about 1m. thick is placed and again compacted. This final thick cover is given to prevent rodents from burrowing into the wastes.

When rainfall percolates through the refuse soluble materials are dissolved and the microbial process of refuse decomposition is stimulated. This yields soluble products which accumulate in the liquid effluent or leachete. To prevent ground water pollution by

leachate plastic membranes and other water-tight linings are being developed.

Advantages:

1. Where land is available a sanitary landfilling is usually the most economical method of solid waste disposal.
2. Initial investment is low compared to other disposal methods.
3. A sanitary is a complete or final disposal method as compared to incineration and composting which require additional treatment or disposal operations for residue, quenching water, unusable materials etc.
4. The public health problems are minimized because flies, rats and other pests are unable to breed in the covered refuse.
5. Fire hazards are minimized.
6. A sanitary lanfill can receive all types of wastes eliminating the necessity of separate collection.
7. A sanitary landfill is flexible. Increased quantities of solid wastes can be disposed off with little additional personnel and equipment.
8. Submerginal land may be reclaimed for use as parking, lots, playgrounds, golf courses, air ports etc. Thus a sizable area of land becomes readily available for other purposes.

On the other hand landfilling have some shortcomings also. These are as follows ----------

i) It creates underground water water pollution. In our country average ground water level is not far below from the earth surface.

So ground water may easily be contaminated. In developed countries suitable linings are being used to stop this kind of pollution.

ii) In presence of water landfilled was produces leachate, a liquid which is a potential pollutant. In some cases it is practised that leachate is collected by pumping and used for bio-gas production. It is a good practice which also gives a lot of financial benefits.

iii) Landfilling requires costly land areas. Sometimes landfilling costs are over $100/tonne (31).

Landfill site selection:

Factors that must be considered in evaluating a potential solid waste disposal site include ----------

i) Available land area.

ii) Impart of processing and resource recovery.

iii) Soil characteristics and topography.

iv) Ground water level.

v) Potential ultimate use of the completed site.

vi) Geologic and hydro-geologic conditions.

vii) Flood levels.

viii) Access to transportation and acceptability.

ix) Local environmental conditions.

x) Climatological conditions.

4.9. SPECIFIC WASTE MANAGEMENT PROBLEMS:

1. Water pollution:

The use of Chaktai Khal and other canals for unauthorised waste disposal is a potential cause for water pollution in Chittagong City Corporation. Water drainage system is frequently being impaired due to blockade of this canal, and other streams, ditches and gullies by solid wastes. Water can also be polluted through infiltration of leachete from solid wastes to static water at dump sites. Proper enactment of legislation is necessary to prevent this sort of foul practices. Pollution of water is also causing serious shortage of fishes. Water treatment is also becoming more difficult for tremendous water pollution. If these continues cultivation of crops by pumping water from these polluted water resources will be also dangerous.

2. Obnoxious odours and air pollution:

Open communal storage, dump sites and open collection trucks produce obnoxious odours. Wastes are accidentally blown away into the streets during collection and transportation or scattered by stray dogs, animals and illegal scavengers at the storage locations. Often times garbage collectors are also too careless in transferring the refuse from containers to the dump trucks causing scattering of litters and refuse on the streets. Temporary storage burning of refuse at road corners and roadside and traffic congestion during transportation of waste sometimes also cause air pollution. The problem arising from congestion can be avoided by

collection at night and dawn. On the other hand illiterate people disposes wastes in their backyards, vacant lots or into nearby streams and ditches which is a major cause to air pollution. Figure 4.3 shows how land, air and water pollution is directly related to improper functioning of solid waste management.

3. Rodent and insect vectors:

Very large open communal storage and unofficial dump sites together with the universal failure to cover landfill properly encourage the breeding of flies and rodents. The disposal of wastes around the bin by some kinds of unconscious, ignorant people deteriorates the condition.

4. Direct health hazards:

Aside from health risk through these insect vectors, The methods of collection allow the workers to be exposed directly to regular skin contact with wastes which sometimes contain innocuous matter and offensive materials. This accounts for the increased incidence of certain diseases and trauma among refuse collectors. Long handled brooms and handcarts with replaceable containers should be used to improve workers health and safety. Front loading system of vehicle can also be introduced to avoid health hazard.

5. Lack of motor vehicles and equipments:

Almost everywhere in Asia, Collection motor vehicles are not only backdated but too few in number. Poor maintenance and lack of vehicle replacement policy further aggravate the problem. A considerable number of equipments used are no longer in good

working condition. Regular check up of the vehicles and spare parts replacement is rarely practised.

6. Delayed and inefficient refuse collection:

Improper scheduling of collection vehicles causes delay in the collection service. Delayed collection accounts for over spilling of bins, which encourages people to discard waste outside the bin.

7. Narrow streets and alleys:

Handcarts, rickshaws, bullock carts or baskets are used to collect refuse in some old parts of the cities and towns where streets are too narrow to admit large motor vehicles. However it is very common that some of these alleys are just ignored and denied collection causing the accumulation of rotten refuse in yards or on the bank of streams and canals. This is frequently in effect in our municipalities and emits foul odours.

8. Lack of depot of wastes:

Almost everywhere, finding suitable landfill sites is a problem for the municipality due to unavailability of land and the high cost involved in acquiring the land. Often times the landfill sites are outside the city in which transfer and transport add to further increase in cost of operation. In Dhaka and Chittagong which maintain a small fleet of collection vehicles, no vehicle could be spared for other work for an extra time.

There is only one disposal site for CCC in Halishahar. another is private disposal site at Yaqub Nagar of Feringee Bazar for improvement of low lying area on request. The condition is not good

at all, new two is very necessary. DCC is also facing difficulties for new disposal sites. Recently they acquired a piece of 72 acres of land at Matuail just 10 km. apart from head quarter for disposing wastes.

9. Accidental fires and gas leaks:

Accidental fire at a landfill is not surprising and may arise due to several causes: a lighted cigarette thrown down by a careless worker, hot ashes in a vehicle delivering waste, sun's ray through a fragment of glass etc. Fire have often been seen on the surface of landfills in most Asian countries due to high density, high vegetable components of the waste unlike in Europe where serious underground fires have caused the collapse of the surface into voids caused by fire. Toxic gases like carbon mono-oxide, carbon di-oxide, methane and hydrogen sulphide are produced as a result of waste decomposition. These gases produce extremely offensive odour which at certain concentration may cause unconsciousness.

10. Lack of co-operation from public:

Public attitude is one of the major problems in our country. Many public pay very little or no attention to sanitation and usually look for a cheaper short-cut way, particularly of refuse disposal problems. Most people do not care for cleanliness outside their house and home. Management should be convinced to educate people of the community through pamphlets, posters, advertisements, Television and Radio broadcast, news paper articles, firms, slides, school health program etc.

It is observed that only a small percent of people is responsible

for indiscriminate refuse disposal, others are simply reluctant. If mass people can be brought under environmental propaganda, the few culprits will not dare for such malpractice. Management should chalk out specific social motivation program so that level of awareness can be raised alongside they feel sufficient respect for the sanitation work. If this can be continued incessantly co-operation can fully be expected from them.

4.10. PIONEERS IN SWM IN ASIA:

Exception in this region is Singapore, Hongkong and Indonesia. Except these three per capita waste generation rate is very low around 350 gm/head/day indicating low standard of living and a large amount of uncontrolled wastes. For these three countries per capita waste generation rate exceeds 600 gm, representing a characteristics more similar and comparable to some countries in Europe. In this region the solid waste management system of Singapore can be traced as the pioneer for its efficiency.

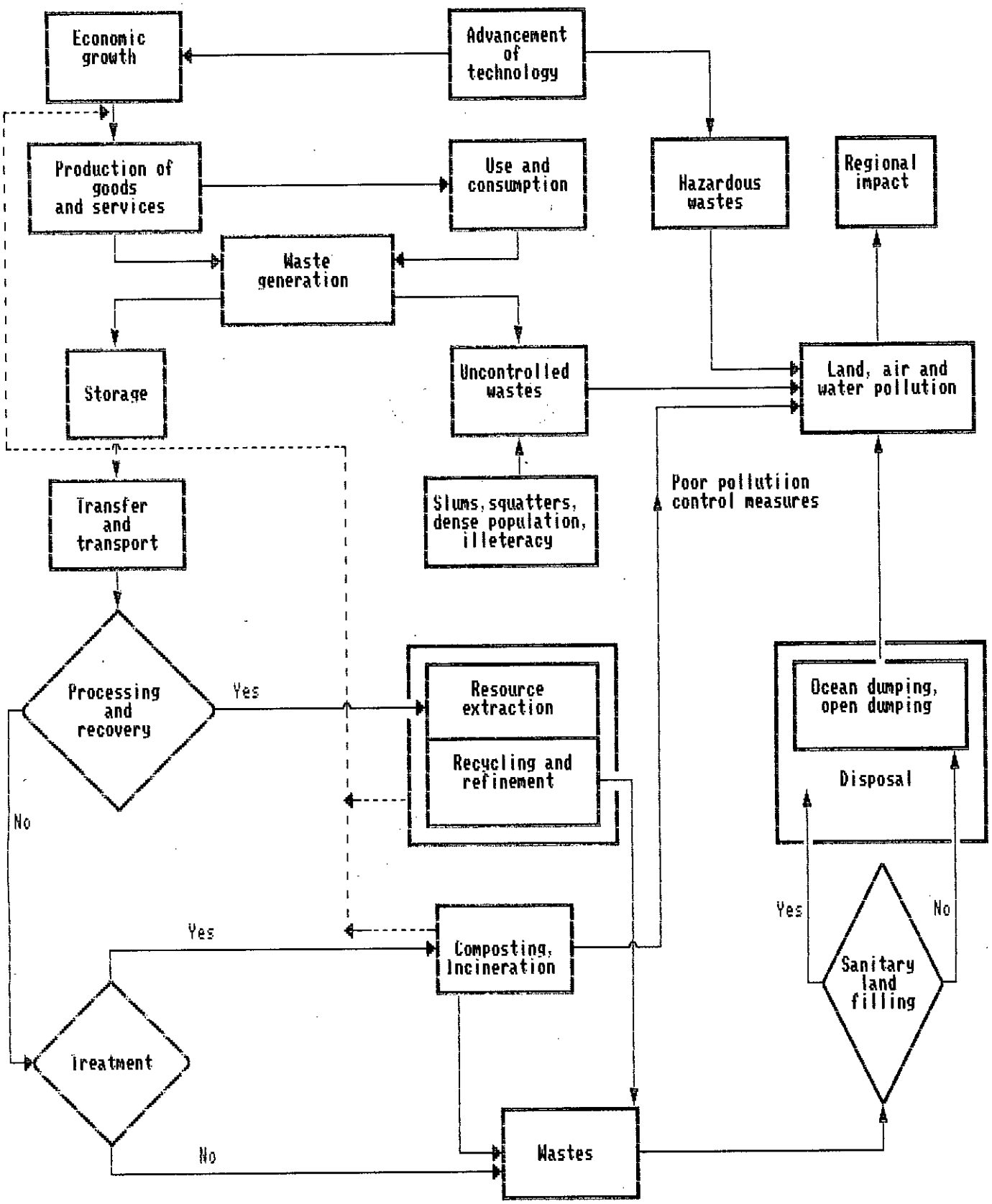


Figure 4.3: Flow diagram showing the impact of poor management of Municipal Solid Waste.

4.10.1. SOLID WASTE MANAGEMENT IN SINGAPORE:

Singapore is most efficient in solid waste management in this region. Almost every countries in Asia, a substantial amount of solid waste produced are not collected. The proportion of uncontrolled waste is lowest in Singapore and the highest in Nepal. The normal performance of a worker (total weight collected divided by total manual employees) in this region is observed as about 250 kg/day, exceptions are Nepal about 50 kg/day, Colombo about 135 kg/day and in Singapore the highest about 1850 kg/day. The introduction of mechanical sweepers in Singapore accounts for the decrease in the labour's work load still maintaining their work productivity. However the equivalent deployment ratio between man and a machine is observed as 16:1. Clamping of stern legislation is also being maintained very strictly in Singapore. even spit or a small piece of paper thrown in the road account for a fine not less than 10 S.D. Table 4.3 shows a comparative data on solid waste management practices in Asia.

Table 4.2: Comparative data on solid waste management in this region. (14,28)

	U.K	INDIA		NEPAL	BANGLADESH		MYNMAR	INDONESIA	SRI LANKA	THAILAND	PHILIPPINES	SINGAPORE
City	Typical	Delhi	Bangalore	Kathmandu	Dhaka	Chittagong	Rangoon	Jakarta	Colombo	Bangkok	Manila	Singapore
Population		4004000	1650000	200000	1311000*	800000	1900000	5000000	580000	3300000	7042492	2300000
Population density/sq.km.	4000	8640	12750	-	19600	7229	3482	8375	15500	11350	11240	3840
Population max. density/sq.km.	12000	250000	70000	56500	38000	-	60600	50000	68000	85900	-	-
Avg. persons/dwelling	3	-	6	6	8-10	8	5-8	8	6	7	-	-
Waste production gm/head/day	900	-	415	250	350	280	250	604	420	455	500	870
Collected gm/head/day	900	-	370	75	305	250	210	404	400	303	-	870
density kg/m^3	150	-	570	600	600	-	400	400	400	250	-	-
Workers/100 population	1.3	3.2	1.8	1.5	1.2	1.1	1.0	1.1	2.8	1.2	1.67	0.5
Wages/hr. US$	2.00	0.13	0.15	0.05	0.13	0.13	0.10	0.08	0.17	0.20	-	-
Kg. collected/worker/day	700	-	257	50	260	227	222	266	135	244	300	1343
Diesel cost US$/litre	0.29	0.13	0.13	-	0.17	-	0.11	0.34	0.16	0.12	0.21	-
Petrol cost US$/litre	0.33	0.40	0.42	-	0.42	-	0.15	0.11	0.41	0.17	0.24	-
Annual expenditure US$/head pop.	10.00	1.06	0.70	0.20	0.32	0.37	0.18	0.40	1.53	0.55	-	-
GNP/head pop. US$	-	(1987)84	(1987)84	(1988)75	(1972)60	(1972)60	(1988)78	(1988)83	(1988)160	(1970)187	(1987)410	2700

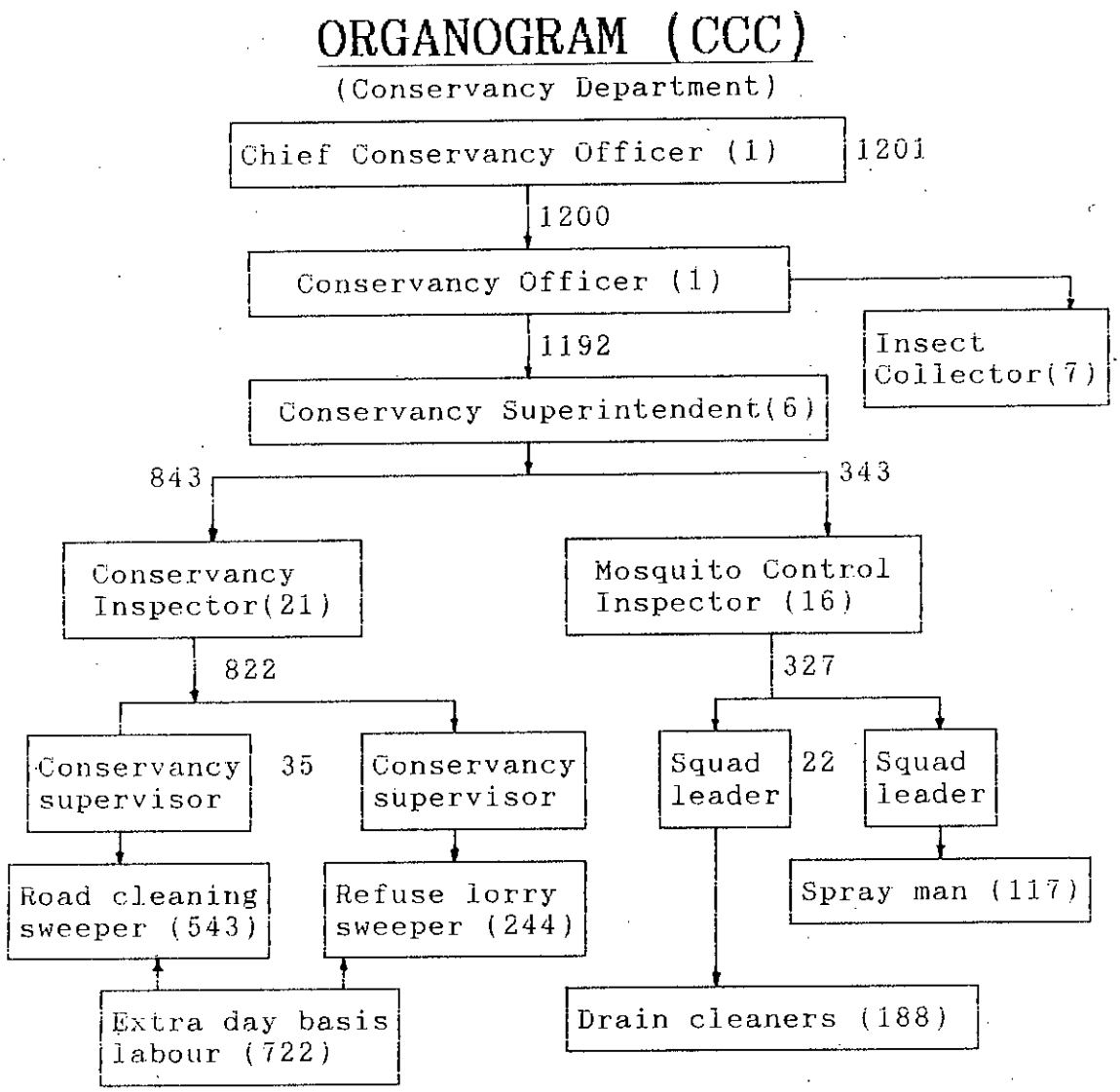


Table 4.4: Present organizational structure of Chittagong City Corporation (ccc).

CHAPTER V

5.1 DATA COLLECTION:

Procedure of data collection should be such that the desired accuracy could be derived with loss of information kept at a minimum level, at the same time there must be a clear understanding of the objectives and requirements.

In the present study the raw data comes from the following sources:

i) Copies of standard operational maintenance or supply forms as used by the system operatives.

ii) Special data forms originated by the study group for a specific requirement for a specific period.

iii) Direct data generation time and work study, discussion with conservancy staffs, tape measurements, experimentation etc.

The basic means of collecting data are the study of procedures, interviewing of departmental representatives and direct time and motion study.

The problems encountered in data collection is a major hinderance toward research in our country, which is also seems to be evident in this case. The sources of data available is in mostly of raw form, unprocessed and uncompelled. proper data storage system is absent and filing of data is maintained very unwisely and unscientifically. The fact in many cases confronted is that the

desired data are not available because of not keeping relevant data records. The formulation of the program from the acquired data is represented in the upcoming chapter.

5.2 PROGRAM FORMULATION:

SHIFTS: In CCC there are two shifts:

Morning shift:

7:00 AM - 2:00 PM (with out any break) = 7 hours.

Noon shift:

2:00 PM - 10:00 PM = 7 hours.

Noon shift is only for refuse collection. No road sweeping, drain cleaning, collection by cane basket and lorry is done in this period i,e. the only labour that involved in this period is truck driver and truck crew.

This seven hour time is not the effective time. Time for different allowances should be deducted from this. Different allowances that have encountered in this study is as follows.

a) Personal allowances: This time is allocated for the personal need fulfilment of the worker, such as going to lavatories, to take water, to smoke etc. Reduction of efficiency due to cold/hot/stormy weather or due to headache or due to other minor diseases also fall under this category. This allowance is considered here as 5 percent of the total time.

b) Fatigue allowances: No worker can work incessantly with the same speed, same attention and with same efficiency or perfection. Every man is a human being, not a remote controlled robot. After sometimes he feel tiredness due to excessive work load, poor working condition, tidiness, monotonous or repetitive nature of job etc. These all factors lead to fatigue. A fatigue allowance does not necessarily mean a misuse of time. This is a well established fact that a fresh man can work more quickly than a tired man. Thus a suitable fatigue allowance should be considered. This allowance is normally taken as 5 percent of the total time and is also used here.

c) Start-up time allowances: This is like the set-up time allowance for a worker working in a workshop. This time is required for issuing the equipment, checking it, minor maintenance etc. Driver should check break, horns, wavers, should fill fuel prior to the beginning of the collection operation. It is taken as 2 percent of the total time here.

d) Break down allowances: Hoe, wheelbarrow or other tools of a cleaner/sweeper may have to be repaired time to time. Vehicle may be out of order, it may need to be taken to the garage for major repair. So break down allowance should be considered. It is taken as 3 percent here.

Thus total allowance = 5 + 5 + 3 + 2 = 15%

Therefore effective time = 7.0 - 7.0 X 0.15

= 5.95 hrs.

Truck loading time:

From the work study it is observed that on an average 285, 150, 100, 60 cft. trucks take 4, 3, 2, 1.5 hrs respectively for loading.

Truck size	Crew size	Time needed	Time needed for a 100 cft capacity with 5 crews
285	5	4 hrs. ..	(4X100)/285= 1.4 hrs.
150	5	3 ,, ...	(3X100)/150= 2.0 hrs.
100	4	2 ,, ...	(2X4)/5= 1.6 hrs.
60	3	1.5 ,, ..	(1.5X100)/60= 1.5 hrs.

Taking the gross average --------

Thus a 100 cft. capacity truck with five crews can be filled up within (1.4 + 2.0 + 1.6 + 1.5)/4 hrs. = 1.625 hrs.

Area and population data are collected and are shown in Table 5.1 and 5.2 below. Note that individual population of wards for ,91 census is not available, so population found from '81 census is simply projected proportionately maintaining the total population equals to census '91.

Table 5.1: Total population data of city corporations in Bangladesh. (18)

Corporation	Wards	Mahallah	Household	Population
Rajshahi	30	166	55010	324532
Khulna	29	163	147901	601051
Dhaka	75	626	644438	3637892
Chittagong	41	123	286107	1566070

Table 5.2: Wardwise area and population data of CCC.

Ward No.	Name	Area (sq.mi.)	Population ('81)	Adjusted for '91.
1*	Bagmoniram	0.66	19687	29916
2*	Chack Bazar	0.67	32948	50067
3*	Jamal Khan	0.36	31266	47511
4*	Enayet Bazar	0.321	21001	31913
5*	Dewan Bazar	0.14	21974	33391
6*	Andorkilla	0.321	8249	12535
7*	Alkoron	0.343	17100	25985
8*	Pathorghata	0.343	29747	45203
9*	Firingy Bazar	0.309	13174	20019
10*	Bashir Hat	0.265	14662	22280
11*	Shoolak Bahar	3.672	47963	72883
12	W. Sholashahar	1.559	28353	43084
13	S. Pahartally	4.131	17675	26858
14	Jalalabad	4.131	39680	60297
15*	Lalkhan Bazar	0.486	70803	107590
16*	E. Madarbari	0.45	30418	4622
17*	W. ,,	0.40	46868	71219
18*	N. Pathantooly	0.252	26864	40822
19*	Pathantooly	0.457	31814	48344
20*	Goshail Danga	0.515	15500	23553

Ward No.	Name	Area (sq.mi.)	Population '81 census	Adjusted for '91
21*	Sarai Para	0.811	25112	38160
22	N. Pahartally	2.111	21856	33212
23*	Pahartally	1.009	12558	19083
24*	N. Agrabad	0.458	16424	24957
25*	S. ,,	0.89	35943	54618
26	Pachlaish	2.217	28526	43347
27*	Chandgaon	3.557	37695	57280
28	Mohora	3.47	34767	52831
29	E.Sholashahar	0.572	22338	33944
30	E. Bakalia	2.51	10490	15940
31	W. ,,	1.283	26275	39927
32	S. ,,	1.35	26836	40779
33*	Rampur	0.734	10861	16504
34	N. Katroly	1.043	17339	26348
35	S. ,,	1.261	538	818
36*	N. Halishahar	2.639	10034	15247
37	N. M. ,,	1.444	17851	27126
38	S. M. ,,	1.719	34879	53001
39	S. ,,	3.579	28989	44051
40	N. Patenga	3.69	22294	33877
41	S. ,,	3.89	23249	35329

Source: Chittagong city corporation (for area data) & (17)

Criteria for allocation of bins:

At first total number of bins are calculated which is just sufficient to preserve the total wastes found from product of per capita waste generation and total population. The program is so formulated that this total bins will be allocated to the individual wards according to area or population basis which basis gives the

highest value.

Off route factors: A off route factor leads to all time spent on activities that are nonproductive from the point of view of the overall collection operation. In our present study it is taken as 11%. The study only considers the unnecessary offroute times such as: time spent for lunch in excess of the stated lunch period, time spent on taking unauthorized coffee/tea breaks, talking to friends, time spoiled due to congestion, traffic jam etc.

Intensity factors:

Data d indicates these factors for individual wards. Municipality do not serve for industries only for industrial areas, also they are not allowed to enter to military compounding, they have their own disposal systems, again level of urbanization is not uniform for all wards, some wards are very busy caused from increased people interactions and consumption of goods and services, thus municipality have to give service twice a day for many potential wards (* mark beside ward number in table 5.2 represents the wards which are normally serviced twice daily), on the other hand very few or on request for some wards. These factors lead to incorporate this data based on present observation to get a more practical people and man power distribution.

Waste generation rate:

As discussed earlier waste generation rate for Chittagong City Corporation is observed 0.25 kg/cap./day for dry season and 0.34 kg./cap./day for summer season.

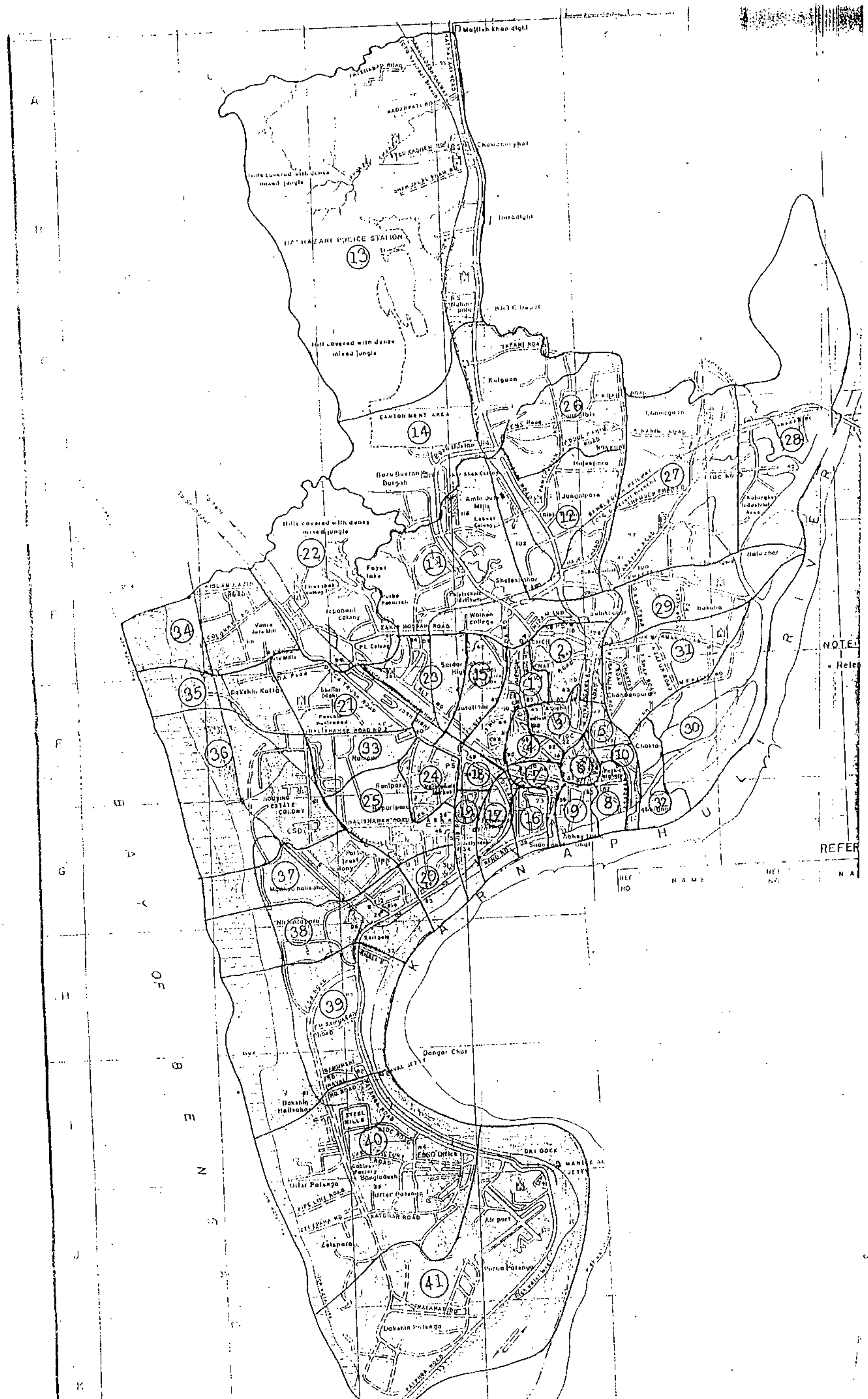
Number of wheelbarrow selection criteria:

It is supposed that all small bins and 50% of the medium bins are situated at the inaccessible areas, narrow streets and alleys, and inside distant residential places. No of wheelbarrow is so programmed that it is sufficient to handle wastes accumulated in these bins. from work study a criteria is taken that a wheelbarrow or handcart can be filled up within 35 minutes. No animal carts or other intermediate vehicles are practised in CCC.

Sizes of bins and barrows has already been discussed earlier.

Round trip haul distance and approach distances:

The haul distances are selected from the city corporation's enlarged map (Map-2) counting approximate road distances. Haul distance is twice the distance from the route to the disposal site. Here individual ward is treated as a route location. Approach distance is the distance from the dispatching point of vehicle to the route location.



HATHAZARI POLICE STATION
Hills covered with dense mixed jungle
CANTONMENT AREA
Kulgaon
Chandgaon
Hills covered with dense mixed jungle
Foyes lake
Chandanpura
Chakta
Bakulia
KARNAPHULI
RIVER
Dangar Char
STEEL MILLS
Dakshin Halishahar
Uttar Patenga
Air port
Dakshin Patenga
NOTE
REFER
NAME

Approach time and trip cycle time:

During approach time calculation truck speed is taken as 20 mile/hr., because the vehicle is unloaded and the city is yet to become busy then.

During calculation of trip cycle time average truck speed is taken as 15 mile/hr. due to congestion and other factors. As already stated this time has three parts, i) loading time ii) unloading time, iii) round trip time. upon observation it is taken that a 100 cft. truck can be unloaded within 25 minutes by 5 truck crews.

Overloading factor:

It is observed that approx. 7% of the total capacity can be overloaded.

Compaction factor:

Upon loading on truck compaction ranging from 8.5 to 13.5% is observed on different trucks (table 2.7). In our study a compaction value of 12% is used.

Drain cleaner and road sweeper selection:

On an average data a drain cleaner gang can gather 1 tonne of waste per day and a road sweeper gang can gather only 10% wastes of that gathered by D.C. According to volume of work a road cleaner gang may be consist of 5-10 members. For simplicity this size is taken as 5. A drain cleaner gang = 10 workers is used in this program. From work study and upon discussion with the conservancy department a data is selected that 40% of the total waste come from drain

cleaning and road sweeping. Of them 30% is from drain cleaning and the remaining is from road sweeping on weight basis. Number of Drain cleaners and road cleaners is assumed constant irrespective of season and not again computed for summer season.

5.3. DEVELOPMENT OF CHARACTERISTIC CURVE:

The program is a service maximizing type. It is developed taking in mind a high service standard so that each day's waste will be emptied properly each day and no bins should be allowed to fill up to a height of 1 ft. Thus service standard for the model is assumed as 99%. Finally the program reduces the output for each ward so that 75% service standard is affirmed. The reduction factor is picked up from a typical characteristics curve level of performance vs. annual cost. This curve have been drawn from few years annual cost data of the conservancy department of the CCC (figure 5.1). Annual cost consists of four components, fixed capital cost of conservancy vehicles, equipments, chemicals etc., salary cost of staffs, regular labours, day basis labours etc., fuel cost of conservancy vehicles, maintenance and repairing cost.

Table 5.3: Distribution of manpower in conservancy department of Chittagong City Corporation.

Year	1st class	2nd	3rd	4th	Regular labours	Day basis labours	Total	Vacant posts	Existing manpower
'93-'94	2	1	124	6	1070	722	1905	702	1203
'92-'93	2	1	100	30	1000	772	1905	669	1236

Table 5.4: Total strength of vehicles of CCC.

Type	93-94	92-93	91-92	90-91	Avg. cost
Jeep	1	1	1	1	9.0 lakh.
Baby	25	25	21	21	1.3
Double cabin pick up	4	3	-	-	6.0
Single cabin pick up	7	4	2	2	3.0
Ambulence	1	1	-	-	3.5
Old truck	21	21	21	21	3.0
New truck	40	7	-	-	8.0
Hydraulic arear lifter	2	-	-	-	17.0
Pay loader	1	-	-	-	75.0
Road roller	10	10	10	10	3.5
Motor cycle	29	29	23	23	0.55
Garbage cleaning vehicles	21	13	11	10	

Source: Documents of CCC and maintenance personnel.

From table 5.4 it is clear that data for conservancy vehicles are not maintained seperately. For an approximation half of the total relevant vehicles are supposed to work for conservancy department. Therefore Capital cost of vehicles for different years are as below:

'93-'94: 12X1.3 + 8X3 + 12X8 + 29X0.55 = 151.55 lakh.

'92-'93: 12X1.3 + 6X3 + 7X8 + 29X0.55 = 105.55 ,,

'91-'92: 10X1.3 + 6X3 + 5X8 + 23X0.55 = 83.65 ,,

Table 5.5: Cost distribution of conservancy department for past few years (29).

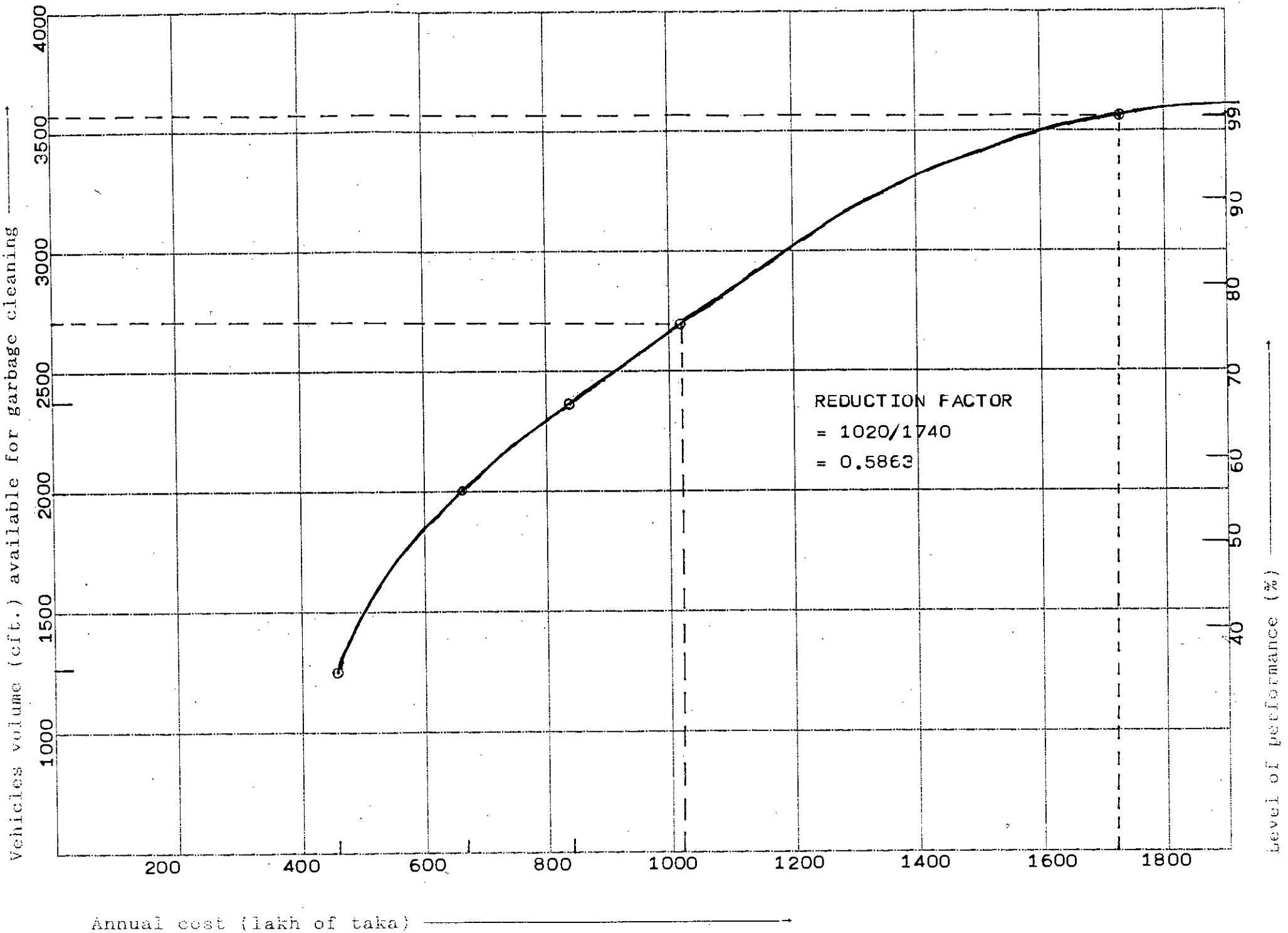
Types of cost	'93-'94	'92-'93	'91-'92
1. Road cleaning and malaria prevention	3100000	2000000	1339317
2. Daily basis labour cost	2500000	1000000	-
3. Garbage cleaning cost	1000000	3000000	3049882
4. Equipment cost for article 1.	600000	-	-
5. Materials, chemicals etc. cost	2500000	-	-
6. Petrol and diesel cost	5000000	2500000	1410361
7. Maintenance and repair cost	2000000	1500000	842721
8. Salary cost of staffs	5000000	4500000	4155840
9. Salary cost of regular labours	47000000	42000000	26271793
Subtotal	68700000	56500000	38339914
capital cost of vehicles	15100000	10555000	8365000
Total (in lakh of taka)	838.55	670.55	467.04

Total vehicle space available/shift for conservancy dept.:

For '93-'94: 1X285 + 4X150 + 13X100 + 3X60 = 2365 cft.

For '92-'93: 3X285 + 3X150 + 7X100 = 2005 cft.

For '91-'92: 1X285 + 10X100 = 1285 cft.


Vehicles volume (cft.) available for garbage cleaning
4000
3500
3000
2500
2000
1500
1000
200
400
600
800
1000
1200
1400
1600
1800
Annual cost (lakh of taka)
99
90
80
70
60
50
40
Level of performance (%)
REDUCTION FACTOR
= 1020/1740
= 0.5863

CHAPTER VI

6.1 OUTPUT OF THE MODEL.

PROJECT OUT FILE

Ward No.	No. of Small Bins	No. of Medium Bins	No. of Big Bins	No. of Shifts	Appro. Vehicle Size
1	3	2	1	1	285
2	3	3	2	1	150
3	2	1	1	1	285
4	1	1	1	1	285
5	1	1	0	1	285
6	1	1	1	1	285
7	2	1	1	1	285
8	2	1	1	1	285
9	1	1	1	1	285
10	1	1	1	1	285
11	17	14	8	2	60
12	7	6	4	1	150
13	19	15	9	2	100
14	19	15	9	2	150
15	2	2	1	1	285
16	2	2	1	1	285
17	2	2	1	1	60
18	1	1	1	1	60
19	2	2	1	1	60

20	2	2	1	1	285
21	4	3	2	1	150
22	9	8	5	2	60
23	5	4	2	2	60
24	2	2	1	1	60
25	4	3	2	1	150
26	10	8	5	2	150
27	16	13	8	2	100
28	16	13	8	1	150
29	3	2	1	1	60
30	11	9	6	2	60
31	6	5	3	1	285
32	6	5	3	2	60
33	3	3	2	1	285
34	5	4	2	1	285
35	6	5	3	1	60
36	12	10	6	2	60
37	6	5	3	1	285
38	8	6	4	1	285
39	16	13	8	2	60
40	17	14	8	2	60
41	18	15	9	1	150

Ward No.	No. of Trucks /week	No. of Truck Crews	No. of Wheel Barrows	No. of Road Cleaners	No. of Drain Cleaners
1	4	5	2	25	15
2	8	5	2	26	15
3	2	5	1	14	8
4	2	5	0	12	7
5	1	5	0	5	3
6	2	5	0	12	7
7	2	5	1	13	8
8	2	5	1	13	8
9	2	5	0	12	7
10	1	5	0	10	6
11	31	14	13	70	42
12	11	7	5	30	18
13	16	7	15	39	24
14	8	5	15	39	24
15	3	5	1	19	11
16	2	5	1	17	10
17	9	4	1	15	9
18	5	3	0	10	6
19	9	4	1	17	10
20	3	5	1	20	12
21	8	5	3	31	19
22	12	6	7	40	24

23	11	5	3	39	23
24	9	4	1	18	11
25	13	8	3	34	20
26	9	6	7	42	25
27	23	10	12	68	41
28	13	8	12	33	20
29	9	4	2	11	7
30	9	4	8	24	14
31	4	5	4	25	15
32	7	4	4	26	15
33	4	5	2	28	17
34	3	5	3	20	12
35	14	7	4	24	14
36	13	6	9	50	30
37	3	5	4	28	17
38	2	5	6	16	10
39	10	5	12	34	21
40	10	5	13	35	21
41	10	6	14	37	22

TOTAL AMOUNT OF EQUIPMENTS AND MAN POWER
FOR CHITTAGONG CITY CORPORATION (Dry season):

Total No. of small bins = 273

Total no. of medium bins = 224

Total no. of big bins = 137

Total no. of road cleaners = 1081

Total no. of drain cleaners = 648

Total no. of wheel barrows = 193

No. of extra trucks (100 cft.)/ shift = 4

Total no. of Truck crews = 227

Total cft. of all the vehicles = 3570

TOTAL AMOUNT OF EQUIPMENTS AND MAN POWER

FOR CHITTAGONG CITY CORPORATION (Summer season):

Total No. of small bins = 276

Total no. of medium bins = 232

Total no. of big bins = 140

Total no. of wheel barrows = 280

No. of extra trucks (100 cft.)/ shift = 12

Total no. of Truck crews = 257

THE END

6.2. FINDINGS AND RECOMMENDATIONS:

Findings:

1. Management should opted for sanitary landfilling and adopt necessary measures in this regard.

2. Project proposal to install a bio-gas plant should be made to determine the feasibility.

3. A small incineration plant can be installed to dispose some special and hazardous wastes as advocated previously.

4. Acquiring new disposal sites are necessary soon.

5. Roadwise route system should be chalked out and followed.

6. On an average another 8 trucks (100 cft. capacity) should be needed to maintain a reasonable service standard. During peak period (summer season) another 4 extra trucks would be necessary to meet the increased quantity of waste.

7. There exists a big gap between generation and collection. It is a indication of improper management of wastes. Thus a large amount of waste is uncontrolled and not being disposed at the definite dustbins. Peak waste generation/day is observed as 550 tonne whereas present waste collection quantity is only 300-350 tonne/day.

8. On an average other required number of equipments and man power as per the model would be as follows:

Total no. of small bins = 275

Total no. of medium bins= 230

Total no. of big bins = 140

Total no. of road cleaners = 1080

Total no. of drain cleaners = 645

Total no. of wheelbarrow and wheelbarrow man = 235

Total no. of truck crews = 240

Thus a total of 645 dustbins should be located and another 500 labours in excess of the existing 1700 would be fine.

9. Equipments and manpower should be deployed with uniformity as per the model to get better utilization.

Recommendations:

1. A checklist of possible and known sources of pollution during discharge to air or water or during transportation to the disposal site should be prepared.

2. The City Corporation should be updated with the latest development both hapenning in the developed and potential developing countries.

3. Standards and measurement techniques of air, water and soil pollution are to be established and followed. So laboratory facility should be incorporated as soon as possible.

4. Necessary physical, chemical and biological tests of municipal solid wastes should be made. A section of the municipality can be authorised for this purpose or by consultancy.

5. Areas of unique archaeological, historical palaeotological

interest should be avoided for disposal, specially in case of landfill.

6. Coastal areas, sea beaches and nearby side of Karnafuli river should be avoided as a disposal site. Washing away of refuse through water current caused by heavy rain fall, tidal bore or floods may contaminate ocean and river water.

7. From ergonomical point of view longhandled brooms, handcarts and replaceable containers should be used for improving worker's health and safety.

8. Establish proper guidelines for the careful management of hospital, pathological and hazardous solid wastes for the workers.

9. Chalk out local laws and regulations in line with corresponding national law and clamp it strictly.

10. Disposal of solid wastes should be done at night or dawn as far as possible. So a third shift (10 P.M - 6 A.M.) is necessary and narrow and busy streets should be served at this period.

11. Busy public gathering, institutional places should be served during the first part of the day. Also wastes generated at traffic congested locations and sources at which extremely large quantities of wastes are generated should be served in the early part of the day.

12. The old backdated route system i,e. definite truck is bound for a definite area named as ward should be discarded and specific routes as roads should be sketched on municipality map which will be available for every drivers and supervisors.

13. Routes should be laid out so that the last waste storage location to be emptied on the route is located nearest to the disposal site.

14. Scattered pick-up points where small quantities of solid wastes are generated and where removal of solid waste is done on request should be chalked out as a separate route and should be serviced during one trip or on the same day to ensure better vehicle utilization.

15. In hilly areas routes should start at the top of the grade and proceed downhill as the vehicles become loaded.

16. Existing system structures such as crew size, number of labours in a gang may be reshuffled for better co-ordination among workers. The figures may be fixed for better recognition and estimation of data as per the model, if possible.

17. Vans, pedal tri-cycles with a box carrier in front, two stroke three wheel motor cycle may be fitted along with handcarts for hauling refuse to narrow streets and alleys.

18. Front loading system of vehicle may be introduced to avoid

health hazard of workers.

19. Wireless sets and motor cycle vehicles for supervisory staffs should be introduced to improve efficiency of workers .

20. Due to lack of funds we cannot adopt latest technology in this stage, used in Singapore, japan and in other European countries. But we can search for obsolete technology of these countries which have just been discarded say one or two years ago with sufficient low cost.

21. We can also go for home made technology for disposal system. It will enable future users of the device to build it entirely by themselves with their own means. Spare parts will be readily available then. For this purpose nursing and promoting of local technical know how is necessary.

22. Develop data and techniques that can be used to design or evaluate new or future system. Information, survey reports and other such documents should be collected, created or prepared and maintained properly.

23. Specific publicity campaign should be continued to educate and aware people about sanitation. Develop approaches for greater involvement of citizens NGO's in ensuring environmental cleanliness.

6.3. CONCLUSION:

There have been advances toward computerized data processing. Thus striking results and better management decisions are possible through this computer application. But in our country researchers frequently faces difficulties of acquiring adequate and reliable data necessary. In this respect our network of information flow may be referred as very weak and should be geared up.

The model is a first approach ever made toward such problem, thus will help the future researchers to a great deal of extent. The model sets a level of performance as 75% and then computes the manpower and equipments. The management can set any cut-off point in terms of the percentage level of performance by simply changing one parameter in the program. Also after few years, with the increase in population, the correct result can also be maintained by only changing the population data. This model always avoids complicated considerations because of increase in volume of work. Such complicated considerations which may have some further indepth contribution to the model and may be a potential subject matter for prospective researchers in this field.

SELECTED BIBLIOGRAPHY:

1. "Waste minimization and cleaner production"

——— Background reading materials of Regional Workshop on 'waste recycling and waste management in developingcountries'.

Organized by ————————

United nations Asian and Pacific Centre for transfer of technology, Bangalore and Centre for Environmental Science & Engineering, Indian Institute of Technology, Bombay.

2. "Hazardous waste management"

——— Background reading materials of regional workshop,

Organized by ————

UN APCIT, India & CESE, IIT, India. 4 - 8 May 1992.

3. Mohammad Shamsuzzoha, "Dry period survey of solid waste in Dhaka City" Solid waste advisor, Implementation support consultant, Environmental Improvement Project, Dhaka City Corporation, Fulbaria. 13th. February 1992.

--- A survey report conducted combinedly by deligates of both Chittagong and Dhaka City Corporation, through 23rd Nov. to 2nd. Dec. 1992.

4. W.A. Hardenbergh & Edward R. Rodie.

"Water supply and waste disposal"

5. Janna Pelkonen, Associate expert, Asian & Pacific Centre for

transfer of technology.

a. Case studies of selected industries is Asia and the Pacific.

b. Statistics of waste production in India, China, Korea and Thailand.

c. Extracts of the report on mechanism for exchange of technology information.

6. George Tchobanoglous/ Hilary Theisen/ Rolf Eliassan. "SOLID WASTES - Engineering principles and management issues"

7. Mr. Paul Kamaleshwar, Chief conservancy officer, Dhaka City Corporation. "Solid waste management in Bangladesh with special reference to the situation in Dhaka", a country report. A paper presented at the consultative meeting on solid waste management held in Delhi, India on 8 - 11 Oct. 1991.

8. Professor Tarafder M. A. I. and Dr. Sk. Akhtar Ahmed, Asstt. Professor, Dept. of OEH, Mohakhali, Dhaka. "Training manual on solid waste management, 'Health & safety'"
A training program conducted by dept. of Occupational and Environmental Health, NIPSOM, Mohakhali, Dhaka -1212 and sponsored by UNCHS under Environmental improvement Project, Dhaka/Chittagong City Corporation 1992.

9. Engineer Abdul Wadud. "Use of waste paper in paper Industry -- Problems and prospects" A paper presented on 37th. annual convention of IEB.

10. Ehlers and Steel. "Municipal and Rural Sanitation".

11. S. Muttamara, Environmental Engineering Division, AIT, Thailand. "Analysis of refuse"

12. Dr. D. Das, Dept. of Chemical Engineering, IIT - Kharagpur. "Solid waste handling and prospects of landfill gas generation"

13. Edwin A. Korzun.
a. "Economic value of municipal solid waste."
b. "Recycling energy values of municipal solid waste."
Part of the Journal of Energy Engineering, Vol. 117, No. 3, Dec. '91.

14. B. N. Lohani & N. C. Thanh, Environmental Engineering Division, AIT, Thailand. "Specific problems of solid waste management in ASIA." Presented at seminar on solid waste management , AIT, Bangkok, Sept. 25 - 30, 1978.

15. "An introduction"
—— The first lesson of the University of Wisconsin/ waste age landfill course.

16. "Journal of Indian Association for Environmental Management." Vol. 16, No. 1 1989.

17. "Small area atlas of Bangladesh."
—— Mauzas and Mahallahs of Chittagong District.

Bangladesh Bureau of Statistics, 1986.

18. BBS, Supplement No. 1. to the preliminary report on population census '91, (adjusted) June '92.

19. Engineer Bhowmick Tarapada. "Operations Research Technique Applied in Replacement of Street Lights of Dhaka City"
A thesis submitted to the dept. of IPE, BUET, Dhaka in partial fulfilment of the requirements for the degree of M.SC. Engg.

20. Sayed Nuruzzaman & Jased Ahmed.
"Powrasava training manual."
21. Khan Sultan Ahmed, "A study of leachate generation and treatment in anaerobic filter with hollow cylindrical clay rings."
A Ph.D. thesis work on solid waste, IIT, Kharagpur, 1991.

22. Report of the task forces of Bangladesh on development strategies the 1990's.

23. World Bank Memorandum '85.

24. BBS, Statistical year book of Bangladesh '88.

25. Chakma S.R. "Urban community development project, Chittagong."
A socio-Economic survey of East Madarbari Bastee, Chittagong, 1983.

26. Ali M. , "The New life Baseline Socio-Economic survey of

Bustuhara of Khulna City." ,1975.

27. Ali Jamaet, A bengali article of "Sangbad Paricrama." A quarterly research magazine of BCSIR, July - Sept. '92.

28. "Solid wastes Management practices in South-East Asia." SEA/EH/Wastes seminar/W.P.3,27 Sept. '78.

29. Annual Budget Report of Chittagong City Corporation of the years '91-'92, '92-'93, '93-'94.

30. Urban, rural and city population 1950-2000, as assessed in 1978, United Nations (ESA/P/WP.66).

31. Haque Md. Anwarul, Rahman Sujan Arifur and Dr. Khan Sultan Ahmed, "Solid waste management - A case study of Chittagong City"

APPENDIX - I:

Sample data for deriving physical characteristics of the MSW of CCC at the disposal site Halishahar over 10 days survey report:

Total quantity of wastes used for survey in one day = 30 no. of cane baskets.

Shape of the basket: Paraboloid.

Diameter at the edge 2r=1'1" =2X0.542 ft.

Depth of the basket h=9" =0.75 ft.

Volume of the basket $=0.5 \times 3.14 \times (0.542)^2 \times 0.75$

$=0.3457$ cft.

Category	No. of baskets out of a total of 30 baskets										Avg.
1. Vegetable/ Putrescribles	9	9	11	8.5	9	7	11	8	8	10	10.15
2. Paper	-	1	1	-	0.5	-	1	-	2	-	0.55
3. Metals	1	0.5	0.5	1	0.5	2	1	0.5	1	1	0.9
4. Glass, Plastic, Rubber, Leather, Polythene, ceramics	3	3	3	3	2.5	2	3	4	2.5	2	2.8
5. Textiles	2	2.5	1.5	1.5	2	2	1	1	1.5	2.5	1.75
6. Wood, Brick, Stone and other building materials	2	2	3	3	2.5	4	4	4	1	2	2.75
7.Drainage, Sweepings, others	13	12	10	13	13	13	9	12.5	14	12.5	12.2

Category	Volume in cft.	Approx. density in Lb/cft.	Weight in Lb.	% in wt. basis
1.	3.51	18.0	63.18	28.4
2.	0.19	5.1	0.969	0.5
3.	0.31	15.0	4.65	2.1
4.	0.97	8.0	7.76	3.5
5.	0.61	4.0	2.24	1.0
6.	0.951	18.0	17.12	7.7
7.	4.218	30	126.54	57

APPENDIX-II:

IDENTIFICATION OF VARIABLES AND CONSTANTS.

NW: Total No.of wards.

NI: A array suffix for individual wards.

AA: Total area of the Municipality in sq. mi.

NTP: Total No.of population of Municipality in (mi)

DATA A: Area of individual Wards in sq. mile.

DATA NP: Population of individual wards.

DATA B: Round trip haul distance for each ward.

DATA C: Types of vehicle sizes available.

DATA NC: No. of truck crews needed for corresponding vehicle size.

DATA D: Intensity factor for each individual wards.

DATA E: Approach distance form the municipality office for each ward.

WR: Per capita waste generation rate (kg/cap/day).

SRVS: Assigned service standard (75%)

DN: Average onsite waste density in kg/m^3.

NRS: Ratio number for small bin.

NRM: Ratio number for medium bin.

NRB: Ratio number for big bin

VDC: Volume (in tonnage) of wastes collected per shift by each drain cleaning gang.

VRC: Volume (in tonnage) of wastes collected per shift by each road sweeping gang.

NRCG: Average number of labourer in each road sweeping gang.

NDCG: Average number of workers in each drain cleaning gang.

RD: Collection of wastes form drain cleaning/ day in percent of total wastes generated.

RR: Total amount of road sweeping wastes/day in percent of total

quantity of wastes generated/day.

OF: Off route factor.

COMP: Natural and/or manual compaction of wastes on truck.

OLF: Over loading factor.

VSM: Small bin's size in cft.

VM: Medium bin's size in cft.

VB: Big bin's size in cft.

VBR: Volume of a wheelbarrow in cft.

WG: Total amount of wastes generated/day in the community.

KK: A intermediate constant appeared (amid calculation) for distribution of total bin volume according to small, medium and big size.

NRC: Total number of road cleaners.

NDC: Total number of drain cleaners.

ANTWB: Average time in minutes needed to fill up a wheel barrow.

NSSUM: Total number of small bins.

NMSUM: Summation of all medium bins.

NBSUM: Total number of big bins.

NRCSUM: Summation of all road cleaners.

NDCSUM: Summation of all drain cleaners.

NWBSUM: Total number of wheelbarrows needed.
It also represents total no. of wheelbarrow man necessary.

NVLSUM: Summation of trucks volume required/ shift.

NETR: No. of extra trucks required/ shift (of 100 cft. capacity).

NTCSUM: Total number of truck crews needed.

VS1: Vehicle size for which transportation as partial loading is a maximum.

VS2: Vehicle size for which transportation as partial loading is a minimum.

VS: Selection of vehicle size from VS1 and VS2 which is more closest to the round figure.

NVS: Integer no. of VS.

NTC1: Number of truck crews corresponding to the vehicle size VS1.

NTC2: Number of truck crews corresponding to the vehicle size VS2.

PI: Ratio of individual ward's population to the total population.

AI: Ratio of individual ward's area to the total area of the Municipality.

NSI: Number of bins for each individual wards.

NMI: Number of medium bins for each individual wards.

NBI: Number of small bins for each individual wards.

NDCI: Number of drain cleaners for each individual wards.

NRCI: Number of rood cleaners for each individual wards.

NV: Total number of vehicle sizes available.

TT1: Time needed corresponding to vehicle size VS1 for one trip.

TT2: Time needed corresponding to vehicle size VS2 for one trip.

TTT: Selection of trip cycle time from TT1 and TT2 corresponding to minimum amount of transportation with partial or fractional loading.

ANT: Number of trips available/shift.

FRN: Fractional value.

BIG: A initialization to fix the biggest fraction, corresponding final value is AMAX.

SMALL: A initialization to fix the smallest fraction, corresponding final value is AMIN.

TR: Total number of trips required each individual Ward.

NTS(NI): Integer number of trips available corresponding to vehicle size VS.

NTRK(NI): Number of trucks needed for each individual ward per

week.

NVOLM(NI): Volume of truck space required for each individual wards.

NSFT(NI): Number of shifts needed for each individual ward.

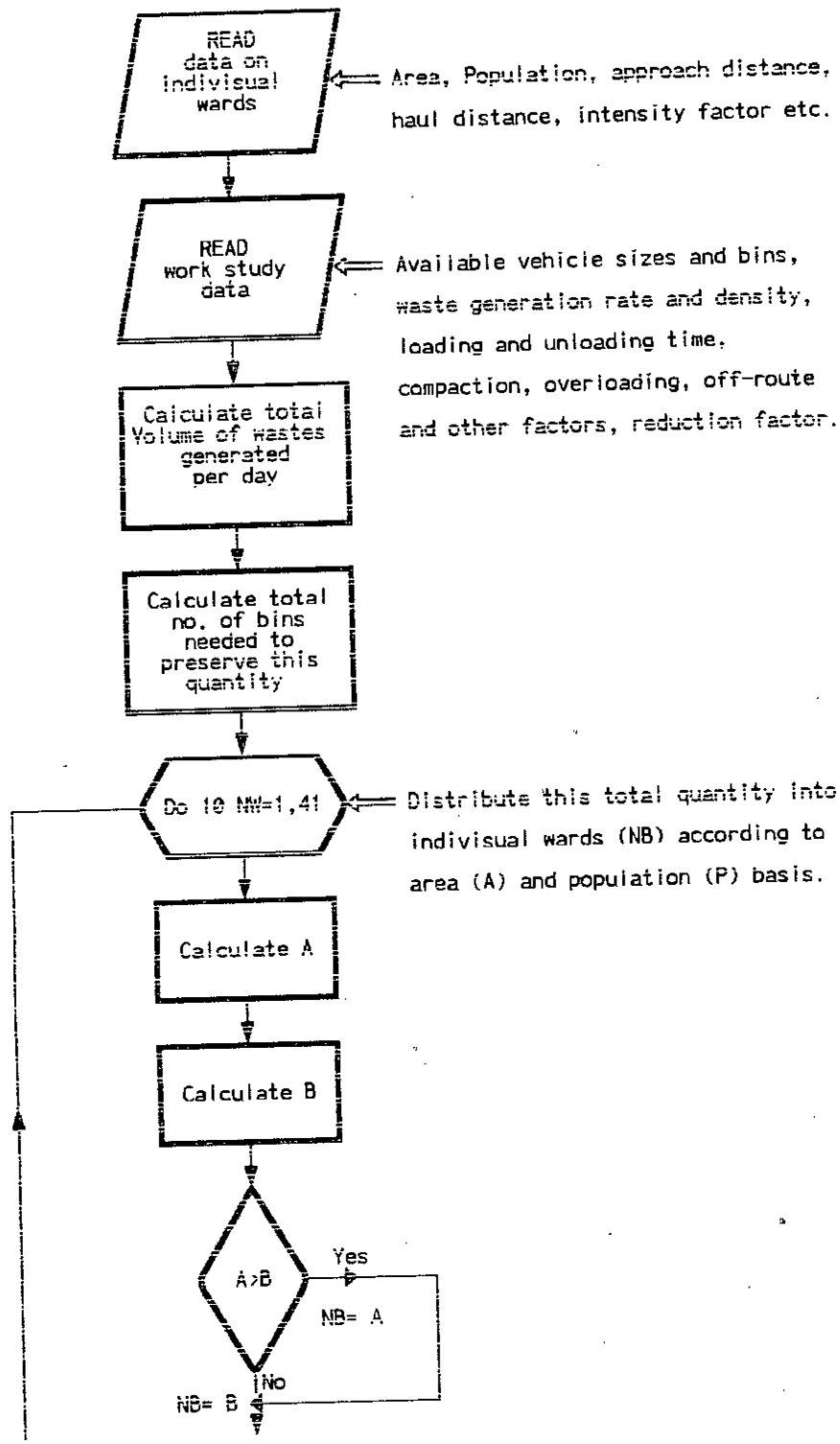
NTCW: Number of individual ward's truck crews per shift.

VHB: Total volume of waste which should be collected from alley side and other not readily accessible area.

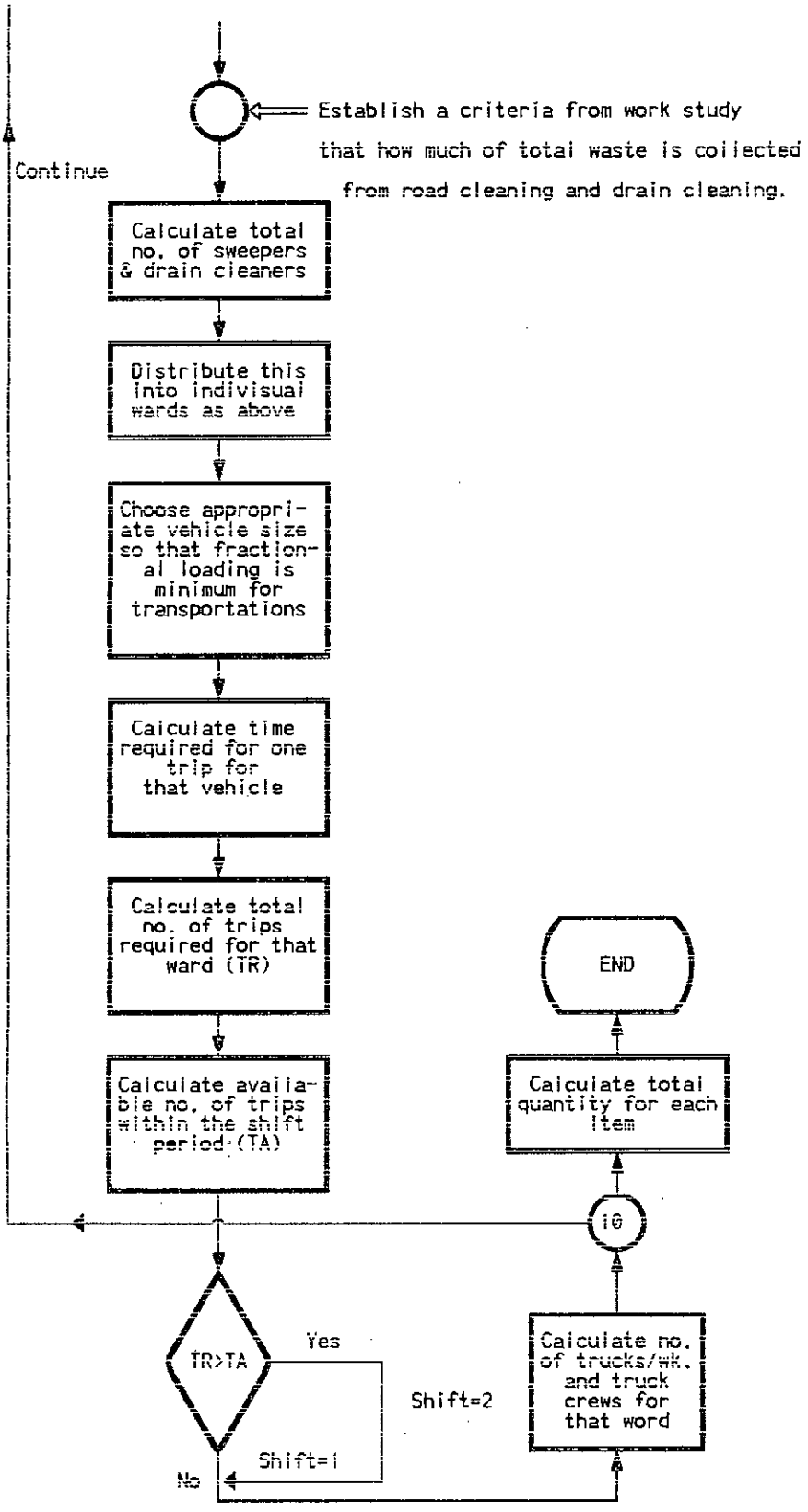
RATIO: A reduction factor as obtained from the characteristic curve.

APPENDIX-III:

(FLOW CHART OF THE PROGRAM)



(CONTINUATION)



APPENDIX-IV:

PROGRAMME MAIN:

```
      parameter (nw=41 )
      dimension a(nw),b(nw),c(4),nc(4),d(nw),e(nw)
     + ,nsi(nw),nmi(nw),nbi(nw),nsft(nw),nvs(nw)
     + ,ntrk(nw),nts(nw),nrci(nw),np(nw)
     + ,ndci(nw),nwbi(nw),ntcw(nw),nvolm(nw)
      open(6,file='project.out ',status='new')
      data a /0.66,0.67,0.36,0.321,0.14,0.321,0.343
     + ,0.343,0.309,0.263,3.672,1.559,4.131,4.131
     + ,0.486,0.45,0.4,0.252,0.457,0.515,0.811
     + ,2.111,1.009,0.458,0.89,2.217,3.557,3.47
     + ,0.572,2.51,1.283,1.35,0.734,1.043,1.261
     + ,2.639,1.444,1.719,3.579,3.69,3.89/
      data np /29916,50067,47511,31913,33391,12535
     + ,25985,45203,20019,22280,72883,43084,26858
     + ,60297,107590,46222,71219,40822,48344,23553
     + ,38160,33212,19083,24957,54618,43347,57280
     + ,52831,33944,15940,39927,40779,16504,26348
     + ,818,15247,27126,53001,44051,33877,35329/
      data b /16.0,18.0,16.0,14.0,19.0,15.0,13.0,17.0
     + ,16.0,15.0,22.0,25.0,35.0,27.0,15.0,12.0,10.0
     + ,9.0,8.0,10.0,12.0,8.0,10.0,8.0,25.0,25.0,30.0
     + ,23.0,19.0,20.0,16.0,10.0,10.0,9.0,7.0,6.0,4.0
     + ,5.0,7.0,5.0,8.0/
      data c  /285.0,150.0,100.0,60.0/
```

```
      data nc /5,4,3,3/
      data d /2.0,2.0,2.0,2.0,2.0,2.0,2.0,2.0,2.0,2.0
     + ,1.0,1.0,0.5,0.5,2.0,2.0,2.0,2.0,2.0,2.0,2.0,1.0
     + ,2.0,2.0,2.0,1.0,1.0,0.5,1.0,0.5,1.0,1.0,2.0,1.0
     + ,1.0,1.0,1.0,0.5,0.5,0.5,0.5/
      data e /3.5,3.0,1.5,1.5,1.5,0.0,1.5,1.5,1.5,1.5
     + ,6.0,6.0,13.0,9.0,4.5,3.5,4.0,3.5,4.0,7.0,8.0
     + ,10.0,5.0,4.5,7.0,9.0,9.0,12.0,7.0,3.0,4.0,2.5
     + ,9.0,10.0,9.0,8.0,8.0,8.0,9.0,12.0,15.0/
      aa=60.0
      wr=0.25
      ntp=1566070
      dn=626.0
      nrs=6
      nrm=5
      nrb=3
      vdc=1.0
      vrc=vdc*0.10
      nrcg=5
      ndcg=10
      rd=0.30
      rr=0.10
      of=0.11
      comp=0.12
      srvs = 0.75
      olf=0.07
      vsm=4.0*4.0*1.50
      vm=6.0*4.0*1.50
```

```
vb=9.0*4.0*1.50
vbr=2.83*1.92*0.79*1.1
wg=ntp*wr*3.281**3/dn
kk=wg/(nrs*vsm+nrm*vm+nrb*vb)
ns=nrs*kk
nm=nrm*kk
nb=nrb*kk
nrc=wr*ntp*rr*nrcg/(vrc*1000)
ndc=wr*ntp*rd*ndcg/(vdc*1000)
antwb=5.95*60.0/35.0
nssum=0.0
nmsum=0.0
nbsum=0.0
nrcsum=0.0
ndcsum=0.0
nwbsum=0.0
nvlsum=0.0
ntcsum=0.0
ratio = 0.586
do  10   ni=1,nw
big=0.000000000003
small=9999999999999.0
vs1=0.0
vs2=0.0
ntc1=0.0
ntc2=0.0
pi=np(ni)/ntp
ai=a(ni)/aa
```

```
      if ( pi.gt.ai ) then
      nsi(ni)=ns*pi*d(ni)+0.5
      nmi(ni)=nm*pi*d(ni)+0.5
      nbi(ni) =nb*pi*d(ni)+0.5
      else
      nsi(ni)=ns*ai+0.5
      nmi(ni)=nm*ai+0.5
      nbi(ni)=nb*ai+0.5
      endif
      if(pi.gt.ai)then
      ndci(ni)=ndc*pi*ratio+0.5
      nrci(ni)=nrc*pi*ratio+0.5
      else
      ndci(ni)= ndc*ai*d(ni)*ratio+0.5
      nrci(ni)=nrc*ai*d(ni)*ratio+0.5
      endif
      do    14  nv=1,4
      if (nv -3) 11,22,33
11    tt1 = ((c(nv)+(1.0+comp+olf))*1.625/100+b(ni)
     + /15)*(1+of)+25.0*c(nv)*4.0/(60.0*100.0*5.0)
      go to 35
22    tt1=((c(nv)+(1.0+comp+olf))*1.625*5/400+b(ni)
     + /15)*(1+of)+25.0*c(nv)/(60.0*100.0)
      go to 35
33    tt1=((c(nv)+(1.0+comp+olf))*1.625*3/400+b(ni)
     + /15)*(1+of)+25.0*c(nv)*4.0/(60.0*100.0*3.0)
35    ant=(5.95-2.0*e(ni)/20.0)/tt1
      frn=ant-int(ant)
```

```
      if (frn.ge.big) then
      vs1=c(nv)
      ntc1=nc(nv)
      big=frn
      endif
14    continue
      amax=big
      do  13 jv=1,4
      if (jv -3) 12,24,36
12    tt2 =((c(jv)+(1.0+comp+olf))*1.625/100 +b(ni)
     + /15)*(1+of)+25.0*c(jv)*4.0/(60.0*100.0*5.0)
      go to 39
24    tt2= ((c(jv)+(1.0+comp+olf))*1.625*5/400+b(ni)
     + /15)*(1+of)+25.0*c(jv)/(60.0*100.0)
      go to 39
36    tt2 =((c(jv)+(1.0+comp+olf))*1.625*3/400 +b(ni)
     + /15)*(1+of)+25.0*c(jv)*4.0/(60.0*100.0*3.0)
39    ant=(5.95-2.0*e(ni)/20.0)/tt2
      frn=ant-int(ant)
      if(frn.le.small)then
      small=frn
      vs2=c(jv)
      ntc2=nc(jv)
      else
      endif
13    continue
      amin=small
      if ((1-amax).lt.amin) then
```

```
      vs=vs1
      ttt=tt1
      ntc=ntc1
      else
      vs=vs2
      ttt=tt2
      ntc=ntc2
      endif
      nvs(ni)=int(vs)
      ants =(5.95-2.0*e(ni)/20.0)/ttt
      nts(ni)=int(ants+0.5)
      tr=(amax1((wg*pi),(wg*d(ni)*ai)))*srvs/vs
      if  ((tr/ants).lt.2.0)then
      ntrk(ni)=int(tr*7.0/ants+0.5)
      nsft(ni)=1
      else
      nsft(ni)=2
      ntrk(ni)= (tr*7.0/(2.0*ants)+0.5)
      endif
      nvolm(ni)= ntrk(ni)*nsft(ni)*nvs(ni)
      ntcw(ni)=ntrk(ni)*ntc/7.0+1.0
      if (ntcw(ni).lt.ntc)then
53    ntcw(ni)=ntc
      else
      endif
      vhb=nsi(ni)*vsm + 0.5 * nmi(ni)*vm
      nwbi(ni)=vhb/(vbr*antwb)
      nssum=nssum+nsi(ni)
```

```
      nmsum=nmsum+nmi(ni)
      nbsum=nbsum+nbi(ni)
      ndcsum=ndcsum+ndci(ni)
      nrcsum=nrcsum+nrci(ni)
      nwbsum=nwbsum+nwbi(ni)
      nvlsum=nvlsum+nvolm(ni)
      ntcsum=ntcsum+ntcw(ni)
10    continue
      nvlsum=nvlsum/14
      netr=(nvlsum*srvs-2265)/100
      write (6,400)
400   format ('1',///t23,'PROJECT OUT FILE'/5x,60('=')//)
      write (6,401)
401   format ( t7,'Ward',t17,'No. of',t27,'No. of',t37
     + ,'No. of',t47,'No. of',t57,'Appro.'/t7,'No.',t17
     + ,'Small',t27,'Medium',t37,'Big',t47,'Shifts',t57
     + ,'Vehicle'/t17,'Bins',t27,'Bins',t37,'Bins',t57
     + ,'Size'/5x,60('=')//)
      do  31  ni =1,nw
      write(6,700)ni,nsi(ni),nmi(ni),nbi(ni)
     + ,nsft(ni),nvs(ni)
700   format( t7,i5,t17,i5,t27,i5,t37,i5,t47,i5,t57,i5/)
31    continue
      write (6,402)
402   format (/////// t7,'Ward',t17,'No. of',t27,'No. of'
     + ,t37,'No. of',t47,'No. of',t57,'No. of'/t7,'No.'
     + ,t17,'Trucks',t27,'Truck',t37,'Wheel',t47,'Road'
     + ,t57,'Drain'/t17,'/week',t27,'Crews',t37,'Barrows'
```

```
     + ,t47,'Cleaners',t57,'Cleaners'/5x,60('=')//)
       do 37  ni=1,nw
       write (6,900)ni,ntrk(ni),ntcw(ni),nwbi(ni)
     + ,nrci(ni),ndci(ni)
900    format (t7,i3,t17,i5,t27,i5,t37,i5,t47,i5,t57,i5/)
37     continue
       write (6,222) nssum,nmsum,nbsum,nrcsum,ndcsum
     + ,nwbsum,netr,ntcsum,nvlsum
222    format (///t10,'TOTAL AMOUNT OF EQUIPMENTS AND MAN POWER'
     + /t10,'FOR CHITTAGONG CITY CORPORATION :'/10X, 50('=')/
     + /t13,'Total No. of small bins =  ',i9///12x,
     + 'Total no. of medium bins = ',i9///12x,
     + 'Total no. of big bins = ',i9///12x,
     + 'Total no. of road cleaners = ',i9///12x,
     + 'Total no. of drain cleaners = ',i9///12x,
     + 'Total no. of wheel barrows = ',i9///12x,
     + 'No. of extra trucks (100 cft.)/ shift = '
     + ,i9///12x,'Total no. of Truck crews = 'i9////6x,
     + 'Total cft. of all the vehicles = '
     + ,i9///12x,25('='), 'THE END',27('='))
       stop
       end
```