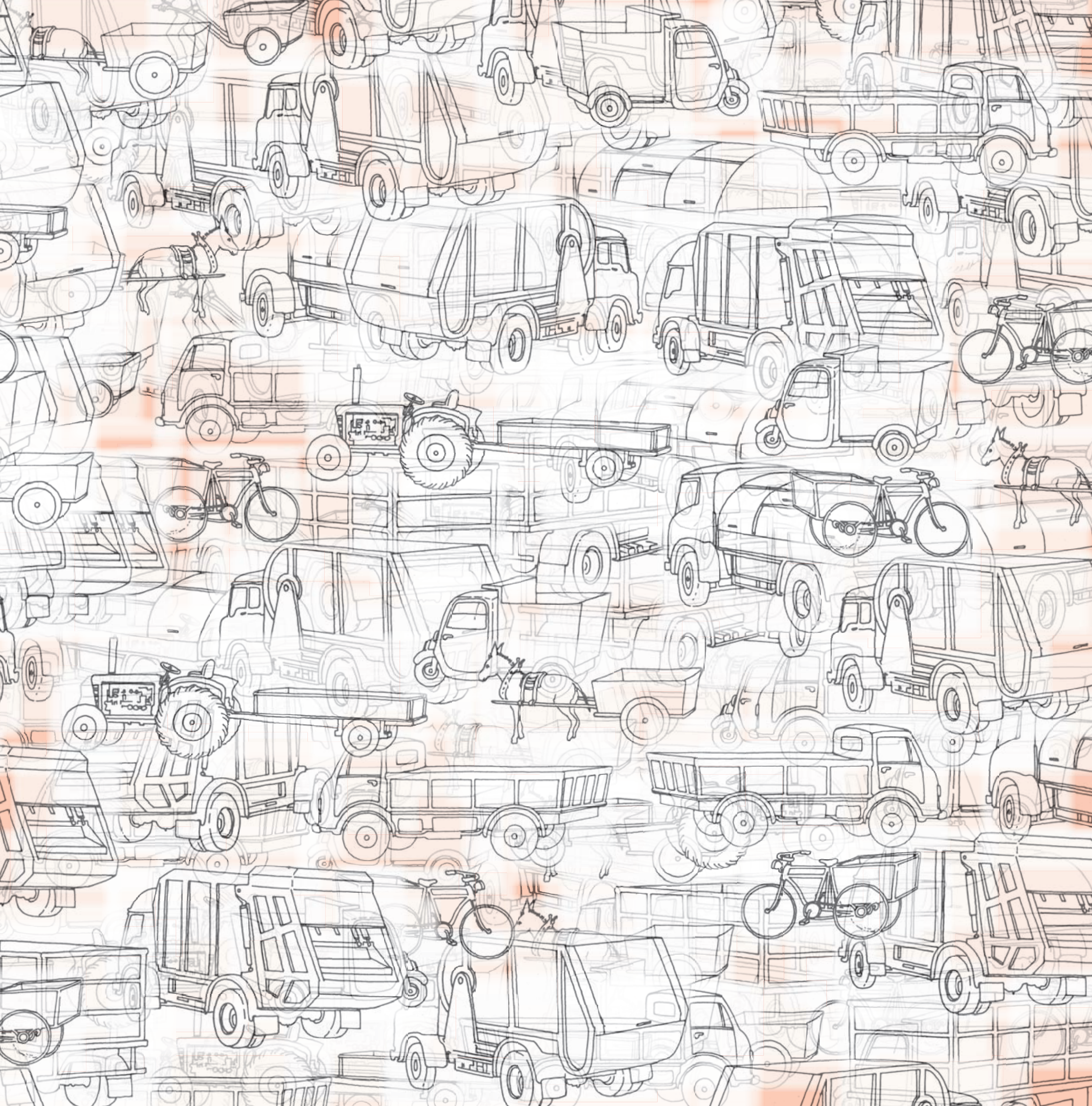


Collection of Municipal Solid Waste in Developing Countries

UN-HABITAT
FOR A BETTER URBAN FUTURE

HS/139/10E
ISBN: (Volume) 978-92-1-132254-5

United Nations Human Settlements Programme (UN-HABITAT)
P.O. Box 30030, Nairobi 00100, Kenya
Tel +254 20 762 3120
Fax +254 20 762 3477
www.unhabitat.org

Authors: Manus Coffey & Adrian Coad
Design and layout: Daniel Vilnersson
Printed by Gutenberg Press, Malta, 2010

Collection of Municipal Solid Waste in Developing Countries

UN HABITAT
FOR A BETTER URBAN FUTURE

TABLE OF CONTENTS

FOREWORD

One of the most intractable problems for local authorities in urban centres is the management of solid waste. Efficient waste management requires considerable political commitment, sufficient budgetary allocations, and a dedicated work force. Deficiencies in management of solid waste are most visible in cities and towns of developing countries, with many areas within these urban centres receiving little or no attention at all. Rapid urbanisation, low levels of revenue collection and competing needs have combined over recent decades to place an inordinate strain on the capacity of many local authorities to deliver efficient waste management services, steadily reducing their areas of service coverage and diminishing the quality of services offered. Consequently, efforts by many local authorities to manage urban solid waste have failed to keep pace with demand. The insidious social and health impact of this neglect is greatest among the poor, particularly those living in informal settlements.

Inappropriate technological choices, particularly in small and medium sized towns, have led to unaffordable costs, bringing the entire solid waste management process to a halt. This publication is UN-HABITAT's response to the glaring need to improve urban waste collection systems. It provides a menu of choices from which service providers and local authorities can identify appropriate, cost effective, and affordable options for efficient solid waste collection, handling and disposal systems.

Lessons drawn from various cities indicate that sustainable waste collection systems for towns and cities in the developing world can only be achieved through the adoption of appropriate technological options designed to meet varying needs. Such equipment must be affordable and easy to operate and maintain, with ready availability of spare parts on the local markets. Sophisticated imported equipment, mostly procured by towns and cities through donor support, has often not lasted long, quickly becoming moribund and creating equipment graveyards at the local authority depots.

This publication will be a valuable tool for policy makers, municipal engineers, independent service providers, planners, consultants, researchers and other professionals engaged in designing solid waste management systems in the towns and cities of the developing world. It is our hope that the principle of technological choice and design demonstrated in this publication will guide solid waste collection, handling and disposal, thereby inspiring many local authorities to commit themselves afresh to creating a waste free environment that will enhance the quality of life for their residents. It should serve as a useful starting point in raising awareness about the potential social and economic gains to be made from adopting appropriate and efficient solid waste management systems, as well stimulate increased international interest in broadening the scope of research to further improve waste collection, handling and disposal technologies.

Anna Kajumulo Tibaijuka
Under Secretary General and Executive Director
United Nations Human Settlements Programme
UN-HABITAT

ACKNOWLEDGEMENTS

During the 1980s UN-HABITAT was involved in a variety of technical cooperation projects specifically focused on solid waste management. Applied research was also undertaken on refuse collection and handling. At the time, it was decided that good practices from the field should be properly documented so others could learn for the experience, resulting in a publication produced in 1988 that was so successful it is still in use. Two years ago it was decided to update and expand the publication to highlight advances in technology and to also include the additional experience gained since the original publication.

Fortunately, the Author of the original publication Mr. Manus Coffey is still very active and was the perfect choice to update and expand the publication. He joined hands with Dr. Adrian Coad to undertake the assignment. The two principal authors were supported by a small team and they wish to express their gratitude to the following for their contributions towards the preparation of this book:

To Uto Hogerzeil, who prepared most of the line drawings. Many of his drawings in the earlier edition of this book have been widely used by others, showing that they are regarded as a very useful resource;

To WEDC, Loughborough University, for access to their Resources Centre, and particularly to Tricia Jackson for assistance in the review of recent literature; and

To the reviewers of the complete draft – Manfred Scheu and Dr Mansoor Ali – who provided many useful suggestions which have improved the quality of the final draft, and also to Iole Issaias who reviewed an earlier draft.

Many members of staff at UN-HABITAT assisted with the preparation and final editing of this study. The report was prepared under the overall substantive guidance of Dr. Graham Alabaster, Chief Secion I, Water Sanitation and Infrastructure Branch, supported by Mr James Ohayo, Mr Daniel Vilnersson and others.

Bert Diphoorn
Director, Human Setttlements Financing Division
United Nations Human Settlements Programme
UN-HABITAT

INTRODUCTION

1

1.1 INTRODUCING THE SUBJECT

When many people hear the term "*solid waste management*[1]" they think immediately of *recycling*[2]. Certainly recycling is an important component of solid waste management, but it is not the aspect that requires the greatest expenditure, and it is not the aspect that has the greatest impact on the urban environment or on public health. According to both criteria, it is the *collection* of municipal solid waste that is the most important aspect. In some situations recycling provides more employment and there are cases where unsatisfactory dumping of wastes has caused very serious pollution, but the collection and transporting of solid waste make the biggest demand on municipal budgets and have the greatest impact on urban living. This publication focuses on the collection of solid wastes.

The term "solid waste collection" is taken to include the initial storage of waste at the household, shop or business premises, the loading, unloading and transfer of waste, and all stages of transporting the waste until it reaches its final destination – a treatment plant or disposal site. The sweeping of streets and public places, the cleaning of open storm drains and the removal of these wastes are also included.

This book is a revision of the UNCHS [Habitat] publication "Refuse Collection Vehicles for Developing Countries" which was published in the 1980s and has been out of print for some time. Compared to the literature available on recycling and disposal, it seems that there are very few sources that deal at length with solid waste collection in low- and middle-income countries, and so the authors and publisher hope that this book will meet a real need.

The expression "*integrated* solid waste management"[3] is often used to suggest that the inclusion of the concept of integration ensures success every time. Even before this term was coined, it was widely recognised by successful leaders in solid waste management that all of the *stages* – from generation to final disposal – must be considered when decisions about any one stage are being made. It is for this reason that this book discusses briefly the stages of recycling and disposal, even though the topic is waste collection. The recent emphasis on the word "integrated" stresses the importance of considering the viewpoints and perspectives of all *stakeholders* and of considering the range of inputs and impacts – social, economic, political, institutional and technical, together with the central issue of the recruitment, well-being and performance of staff. The contributors to this publication are convinced of the importance of integration in all these ways. However, this book is about the collection of solid wastes, and so it does not give equal weight to other stages of solid waste management. There is some discussion in this publication of recycling and disposal, particularly in Annexes A4 and A5, because of the interrelationships between collection, recycling and disposal – methods of collection exert influences on recycling and measures used for recycling and disposal have major impacts on the design of efficient waste collection systems. However, the main focus of this book is on the collection of waste.

This book is written for low- and middle-income countries, also referred to as "developing countries". Since it seeks to encourage the designing of systems based on local information, the approach is valid in any country. The main focus is on municipal solid waste, which is taken to include waste from households, businesses and institutions, construction and demolition waste in small quantities, general solid wastes from hospitals (excluding hazardous wastes), waste from smaller industries that is not classified as hazardous, and wastes from streets, public areas and open drains. It is not concerned with wastes from agriculture, larger industries or the mining industries which normally handle their own wastes. Such wastes are generated in huge quantities in many countries, but the systems for collecting, treating and disposing of them are separate from the systems used for municipal solid waste.

1. *Many of the terms used in this publication are used in different ways in different countries and by various experts. For this reason the last Annex in this publication provides definitions that explain how specific terms are used in these pages. The reader is invited to flick open this list at regular intervals to check on the terminology used here. The first time that a word in this list appears in the text, it will be shown in italics.*
2. *In this publication, "recycling" refers to all activities that are needed to segregate or extract items and materials from solid waste and to give these materials some economic value. The term "recycling" therefore includes at-source segregation, sorting, handling, transporting, cleaning, size reduction, baling, processing (including composting) and manufacturing.*
3. *For a more detailed discussion of integrated solid waste management see van de Klundert [2001] and Coad [2000]. Details of references are given in Annex A6.*

1.2 THE CURRENT SITUATION

Managing solid waste is one of the most costly urban services, typically absorbing up to 1 per cent of GNP and 20 to 40 per cent of municipal revenues in developing countries. Solid waste management provides employment for up to 6 workers per 1,000 population – a figure that could represent up to 2 per cent of the national workforce. Even so, the service is frequently inadequate, with more than half the refuse generated in urban areas remaining uncollected, and large areas of cities receiving no regular attention. Invariably, the majority of those deprived live in low-income settlements.

The responsibility for providing a solid waste management service generally rests on local government, and a common and fundamental deficiency is the failure of governments to ensure that sufficient funds are available to provide an acceptable level of service. Making matters worse, the limited funds that are available are frequently used to acquire inadequate and, often, inappropriate collection equipment or to maintain an insufficient, obsolete collection fleet. Consequently, the service provided in a majority of developing country cities and towns can, at best, be described as unreliable, irregular and inefficient. Too often the systems used in developing countries have been recommended by overseas consultants from countries with very different economic and social conditions and completely different waste characteristics.

The absence of adequate planning and the use of unsuitable vehicles and equipment have led to a serious wastage of expenditure and effort in this direction. Governments are becoming increasingly aware that the poor quality of service provided in most urban areas, in terms of the quantity of solid waste collected and the environmental protection provided, makes it difficult to justify even the present levels of expenditure in this sector. There is, therefore, increasing demand for greater efficiency. Of the total expenditure incurred in solid waste management, typically 70 to 80 percent[4] is directed towards the collection and transporting of wastes. The objective of an efficient service should, therefore, be the minimisation of solid waste collection costs, together with the provision of an adequate and regular service to all of the target area. In order to achieve these objectives, solid waste management systems should evolve indigenously, based on the quantity and character of the waste, wage rates, national equipment manufacturing and maintenance capacities, current energy costs and various physical, social and cultural characteristics of the communities to be served. Providing an efficient collection service to a city often requires a combination of techniques and equipment, to accommodate the different challenges of the various neighbourhoods within the city. This is discussed further in Section 2.3.

A wide range of refuse vehicle types can be found in developing countries. Two dominant trends regarding the vehicles being used give cause for concern. The first relates to the use of outmoded vehicles which are uneconomical and inefficient. The second relates to the gradual replacement of obsolete refuse vehicle fleets with modern compactor trucks which are totally unsuited for most applications in developing countries. Decision-makers and professionals concerned with solid waste management in developing countries are often unaware of the importance of careful selection of refuse vehicles for local conditions and have little information on the range of vehicles that is available, and so they are not able to select types that would be most suitable. Little serious effort has so far been directed towards promoting the production of refuse vehicles that are appropriate[5] for use in the varied conditions found in the urban areas of developing countries. Instead, there is an ever-increasing trend to transplant refuse collection vehicles and systems that were developed for use in industrialised countries, directly into developing countries. Vehicles are being standardised to the point that large areas of cities and towns cannot be served.

1.3 THE PURPOSE OF THIS PUBLICATION

This book is intended to assist those who influence public and private sector investments in solid waste collection systems in developing countries. It seeks to address decision-makers, solid waste management engineers, consultants who are engaged in the planning and provision of solid waste management systems, manufacturers (as well as potential manufacturers) of refuse collection vehicles, and students learning about solid waste management in low- and middle-income countries. It focuses on the design of collection systems and the selection of refuse

4. *The percentage is probably lower in cities with acceptable disposal systems because of the cost of running a good sanitary landfill. Expenditure saved by more efficient collection could be used to upgrade disposal operations, which are often very inadequate.*

5. *The word "appropriate" is used in its original, broader sense, and not in the sense often understood by the term "appropriate technology". In this book "appropriate" means well suited to the task to be performed, the local economic situation, and the expectations and attitudes of the local people, and able to perform in the local context in a way that is reliable, effective and cost-efficient. Sophisticated and automated technologies are appropriate in certain circumstances and simple technologies are appropriate in other conditions.*

collection vehicles, since thorough and rational planning and assessment at this stage are crucial for overall system efficiency and performance. It aims to create awareness of vehicle design and operational features which are essential for ensuring efficiency in waste collection systems and of the potential roles of alternatives to motorised vehicles. Specifically, the purposes of the report are:

a) to provide information that can lead to the development of reliable and affordable solid waste collection systems
b) to provide technical information for the design and manufacture of alternative vehicles that are well suited to local production, operational capacities and physical conditions, and are more cost-effective than capital-intensive vehicles from industrialised countries in the northern hemisphere.

Whilst the focus of this publication is on waste collection vehicles, it must be remembered that the successful operation of the vehicles depends on the effectiveness of the whole waste collection system, and on a range of other factors, as illustrated in Figure 1.1

1.4 THE SCOPE OF THIS PUBLICATION

As has already been mentioned, this book is concerned with the collection and transportation of municipal solid wastes in low and middle-income countries. There are many factors that impact on the effectiveness and efficiency of a solid waste collection system – local conditions, other aspects of the whole solid waste management system, social, economic, institutional, political, environmental, public health and technical factors, and the range of different groups of people who are involved. This publication seeks to show how all these factors can be integrated in order to achieve a reliable and efficient system.

The next chapter explains why solid waste collection in developing countries is different from solid waste collection in industrialised countries, and illustrates this with many examples of how the approach must be different. This is an important part of the book, because the impacts of these differences are often not understood and the consequences of this lack of understanding are often very unfortunate.

Chapter 3 describes the different types of waste, in terms of source and material, and explains how the properties of the waste affect the selection of collection vehicles.

Chapter 4 discusses waste collection systems as a whole, without going into the details of the storage and transportation systems. The next five chapters discuss in detail the physical components of collection and transport systems, describing in turn

- the means of storing waste before it is collected (Chapter 5),
- street sweeping and the collection of litter, street and drain wastes (Chapter 6),

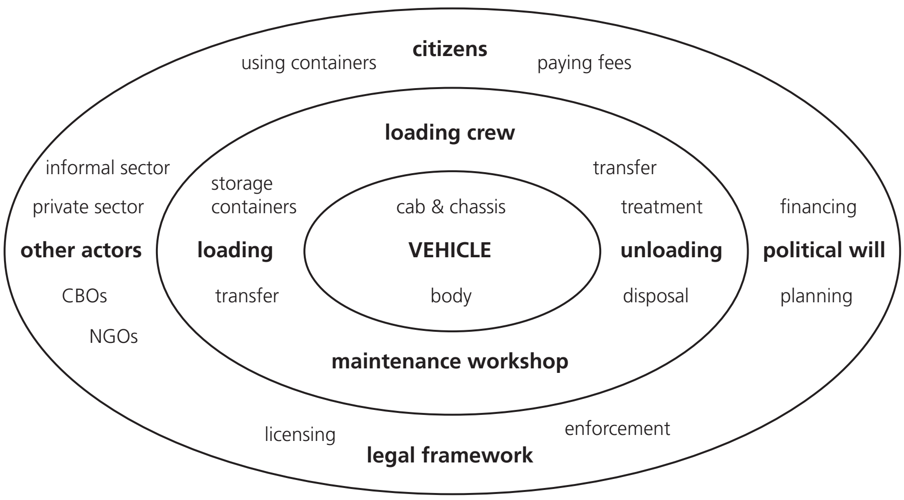


Figure 1.1 The municipal solid waste collection system
The vehicle is the core of the collection system, but there are many other components and aspects that need to be considered. It is not sufficient to select the cab, the chassis (comprising the frame, motor, transmission and wheels) and the load-carrying body without considering the other aspects that are listed in the middle and outer circles. Terms and abbreviations are defined in Annex A7.

- the large range of types of vehicle that can be used for collecting and transporting solid wastes, and the factors to consider when selecting the most appropriate (Chapter 7)
- ways of transferring waste to larger vehicles, especially when the collected wastes must be transported over a considerable distance (Chapter 8), and
- some aspects of operation and how to keep vehicles in good condition so that the waste collection service is as economical and reliable as possible (Chapter 9).

Solid waste collection accounts for most of the expenditure on solid waste management, and solid waste management is often the largest item of expenditure in municipal budgets. The shortage of funds and the difficult procedures involved in accessing funds are often cited as the reasons why important steps cannot be taken (even, as often is the case, when a relatively small expenditure on maintenance can save the larger costs of keeping vehicles idle, awaiting repair). Chapter 10 is concerned with financial considerations linked to waste collection.

Chapter 11 is concerned with institutional aspects of waste collection. Many experts and donor organisations are strongly in favour of involving the private sector in waste collection. Are there ways in which the public sector can deliver similar benefits? What are the different ways in which the private sector can be involved? What are the dangers to avoid when involving the private sector, and what can be done to avoid them? This chapter also discusses the possible roles of the informal sector and suggests reasons for its greater involvement.

Solid waste collection involves a large labour force, particularly in low-income countries where unskilled labourers' wages are very low. In many cases productivity and motivation are also low. Chapter 12 reflects on some of the challenges of managing such a workforce.

The annexes provide more detail and extra information. Annex A1 outlines how valuable data on waste collection operations can be collected. Annex A2 provides detailed and practical information about how vehicle maintenance can be organised. The next annex presents some simplified calculations that show how different waste collection systems can be compared in terms of total unit costs. Annex A4 provides some information about treatment and recycling. Although not within the scope of waste collection, the selection of collection methods and equipment is influenced by these later stages of waste management, and it is for this reason that this brief summary is included. Annex A5 introduces waste disposal and a proposed new approach to operating small landfills. Annex A6 lists the references that have been cited in the text and also suggests books and articles for further reading on various topics. Annex A7, at the end of this book, is a word list. Many of the words used in solid waste management are used in different ways by different people, so this list explains how some of the specific solid waste management terms are used in this book.

The CD that is supplied with this book includes the full text of this publication. It also includes the following materials:

The drawings that are used in this book[6]. Many of these drawings were included in the initial publication and they have been widely used in reports and other publications, and also in lecture notes and students' assignments. To facilitate such usage they are included in the CD.

- Photographs included in this book are also presented in the CD.
- Blank data sheets for preventive maintenance from Annex A2;
- The spreadsheet calculations for the examples given in Annex A3.
- Some of the references listed in Annex A6 area also provided in full. The list of references indicates which references are included.

6. *Material in this book may be used freely provided that the source is acknowledged*

Summary points

- Solid waste management is important for the economy as well as for the environment.
- Solid waste management should be integrated – all stages, impacts and stakeholders should be considered when decisions are being made
- The two main mistakes that are made when choosing vehicles for waste collection in developing countries are (i) to use general-purpose vehicles which are inefficient and not suited to waste, and (ii) to use vehicles that are designed for different conditions in industrialised countries without checking that they are suitable for the particular situation.

INTERNATIONAL DIFFERENCES AND THEIR IMPACTS

2

2.1 INTRODUCTION

One of the main reasons for difficulties and disappointments in the field of solid waste collection is the failure to take account of the important differences between geographical regions, between nations, between cities and even within a city. International consultants, engineers who have studied overseas, and decision-makers who have been impressed by solid waste management systems in other countries, often favour systems that they have seen working well in an industrialised country, and assume that the same systems will work equally well in a completely different context. This is a serious misconception. Decision-makers and engineers may believe that the only significant component in a waste collection system is the technology, and ignore other vital aspects (Figure 1.1). International consultants may prefer systems with which they are familiar, or which are manufactured in their own countries. Too often the result of these influences is extravagant expenditure of foreign exchange, vehicles lying idle awaiting imported spare parts, and waste collection services that are unable to cope with the amounts of waste that are being generated.

The list of differences between one location and another can be very long. They include social, economic, climatic, spatial and urban development aspects, and technical factors. The list provided in Section 2.2 is not complete but suggests the main characteristics of a particular location that should be investigated before a waste collection system is planned and equipment is specified.

Section 2.3 reviews the problems commonly encountered in solid waste systems in low- and middle-income countries and shows that the cause of most of them is the failure to understand and take account of the large differences in challenges and resources from one place to another. The concept of appropriateness is frequently mentioned, and this concept is used in its original sense, referring to a good match between local conditions and the system that is provided, without any prior assumptions about the type of solution that will serve most effectively. *Appropriate* does not always mean simple, low-technology or labour-intensive, but it does mean that all relevant factors of a particular situation are considered when decisions are made.

2.2 INTERNATIONAL DIFFERENCES

2.2.1 Waste characteristics

The impact of waste characteristics (both quantities and composition) on the design and selection of waste collection equipment is one of the major themes of this document. The importance of this cannot be overestimated. Some of the reasons why waste characteristics vary so much are listed here:

- **Cooking and eating habits** – In some countries the shops sell mostly food that has largely been prepared, either frozen or canned. In other countries and in smaller communities, poultry is purchased alive and vegetables are bought with considerable extra material in addition to the part that is consumed (maize is a good example). If fruit and vegetables are cheap and plentiful, and often damaged when being transported, large amounts may be discarded. Different types of fruit and vegetables generate different amounts of waste – compare bananas and watermelons for example. Where significant amounts of fish are consumed, the waste quickly acquires a very strong smell. Cooking (and heating) with solid fuel has a major impact on the waste, because paper, which would otherwise be discarded, may be burned, and hot and abrasive ashes affect the characteristics of the waste, as well as damaging plastic containers and starting fires.
- **Social and economic factors** – Differences in lifestyle can be big, even within one city. This not only affects the type and amount of kitchen waste that is generated, but also the amount of paper (because of higher literacy and the purchase of newspapers and magazines). More affluent citizens are more likely to discard durable items (such as used clothing and electrical equipment) as they become obsolete, instead of repairing them. Some high-income houses may be equipped with garbage grinders for sending their food waste into the sewerage system. The use of domestic servants can also have an impact on the type of waste that is generated.
- **Recycling and reuse** – In some towns much of the waste is fed to livestock and poultry. Food and drinks containers may be reused for household purposes. Certain items may be segregated from the waste and sold. Waste pickers may sort through wastes, taking

out what they can use or sell. Such practices can have a major influence on the waste that is put out for collection.

- **Architecture** – In cities where the housing is constructed mainly of mud brick and the floors and courtyards are not paved, there are large quantities of soil and dust in the waste. Sweeping of unpaved roads also increases the amount of soil in the waste. The lack of adequate toilets may increase the amount of excreta in the waste.
- **Climate and geography** – Heavy rainfall increases the moisture content of solid waste stored in the open. In tropical climates large amounts of vegetation can be expected in the waste, and seasonal climates may result in huge piles of leaves during certain times of the year. Some cities accumulate large quantities of fine wind-blown soil. The climate also influences the types and yields of crops, and therefore the food wastes generated by residents, e.g. sugarcane waste in countries where vendors sell cane juice on the streets may result in huge amounts of crushed cane during certain seasons.

The characteristics of municipal solid waste are also influenced by the definition of the term. In some situations, construction and demolition debris may be included with domestic and institutional wastes, and this inclusion can have a significant influence on the overall weights and characteristics of the waste that is collected.

2.2.2 Social and economic factors

Apart from the nature of the waste, there are other impacts of social and economic factors which must be considered when designing a system.

- **Service level** – The frequency and convenience of the waste collection service that is expected by the population cannot be ignored when planning collection systems. As an illustration, many residents of Cairo expect a daily collection service, the waste being picked up outside the apartment door, even on the tenth floor. In contrast, residents in Switzerland are prepared to carry their waste to a shared container at street level, whereas Cairo residents are reluctant to be seen carrying their wastes. Householders in England are becoming accustomed to having their non-recyclable waste (including kitchen wastes) being collected once every two weeks. As will be discussed in Section 2.2.3, the ambient temperature has a strong influence on the length of time that food wastes can be stored and therefore on the frequency at which they should be collected.
- **Labour costs and unemployment** – Because of high wage levels, industrialised countries have developed capital-intensive technologies for collecting solid waste in order to keep wage bills and total costs down to the minimum. Low-income countries at the other extreme have large pools of unemployed labourers who are willing to work for very low salaries, and in such cases labour-intensive methods may be appropriate. When this phenomenon is coupled with the problems some developing countries experience in keeping sophisticated vehicles and other machines in good condition, labour-intensive methods become attractive because of their economy and reliability. Managing large teams of labourers in an effective way is quite a challenge.
- **Willingness to pay** – In some cities there is an almost universal conviction that municipal authorities should provide a waste collection service without charging directly for it. Other communities may be accustomed to making their own arrangements for waste collection and paying for this service directly. Any plan to finance a solid waste management system from user charges must take into consideration local attitudes and the existing situation.
- **Attitudes to littering** – Some social groups are very careful to always put all their waste inside the appropriate container, whereas others regard the street as an appropriate place for dumping litter and domestic waste (even though they keep their houses and yards very clean). It is easy to write in a project proposal that a programme of public education will change this attitude, but in practice education alone may not be effective in changing habits.
- **Environmental awareness** – Since the 1960s there has been a gradual process of extending the boundaries of environmental concern, from neighbourhood to nation, and now, with the concern about climate change, to the global level. However, this process is at different stages in different countries and is proceeding at different speeds. Therefore it cannot be assumed that householders will be interested in whether their waste is dumped illegally or taken to an approved disposal site, provided that it is taken out of the immediate neighbourhood. This is often referred to as the "NIMBY" factor (*Not In My Back Yard*). City officials may show the same lack of concern with regard to the destination of the waste, and may give solid waste management in general a low priority. A low level of environmental awareness among the public may make it difficult to implement household segregation into two or more waste streams. This lack of awareness is often accompanied by the lack of

any effective enforcement mechanism to ensure correct use of waste storage facilities.

All of these factors can have an influence on the success or failure of a waste collection system, and so should be considered when any system is being designed.

2.2.3 Other international variations that affect collection systems

Ambient temperatures affect the frequency at which waste should be collected. At high temperatures the breeding cycle of houseflies is much faster (Box 2.1), and so the waste should be collected more frequently to control the numbers of these insects. Higher temperatures also accelerate microbiological processes, leading to quicker generation of offensive odours and earlier production of fungal micro-organisms that can cause lung disorders. As a result, solid wastes should be collected at least twice a week in hot climates, whereas a monthly collection would probably cause no problems in the sub-zero temperatures of a northern winter. Daily collection may be necessary in hot climates where fish are a major part of the diet, since fish wastes quickly generate very offensive odours.

The layout of urban areas and road conditions also affect how a waste collection system should be designed. Traditional core areas of old cities and unplanned slum areas pose a particular problem because of narrow access routes and the lack of space for refuse containers. Steep gradients and unsurfaced roads may prevent certain types of vehicle from being used. Weight limits for roads and bridges must be respected in selecting equipment, keeping in mind that some types of waste collection truck are often overloaded. Wherever there are poorly surfaced roads with inadequate foundations, refuse vehicles with excessive axle loads can be a major factor in damage to water pipes underneath the roads resulting in excessive water wastage, often in countries where water is scarce.

The capacities and experience of local administrations should also be considered when planning improvements to waste management systems. In industrialised countries, the evolution of waste collection systems, particularly in terms of management, efficiency and reliability, has taken decades, so it is unrealistic to expect that the same process can be achieved in a low-income country in three months, or even three years. Solid waste management is primarily an engineering function but it is common to find that municipal waste management is the responsibility of the Medical Officer of Health or some other administrative official who has no background in vehicle operation and cannot be expected to make complex decisions concerning the choice of vehicles of which he or she has no experience.

Access to spare parts is another issue that must be considered. Whereas a maintenance manager in an industrialised country may be able to obtain a spare part within hours of realising that it is needed, in a developing country, the process of acquiring spare parts can take more than six months, because of restrictions on foreign currency, bureaucracy and customs procedures. This issue alone can have a major impact on the type of vehicle that should be selected. The lack of well-equipped maintenance workshops is another aspect to be considered.

Legislation and, more importantly, the enforcement of legislation, have a significant impact on waste management. These factors are closely linked to public attitudes and awareness, and also to the willingness to pay for waste collection services. To be effective, legislation needs to have the general support of the public, being regarded as necessary and appropriate. Inspectors and others involved in enforcing the law should be motivated by the convic-

Box 2.1 Additional information

Know the enemy – some information about fly breeding

Female houseflies lay eggs in batches of around 120. One of the preferred sites for laying eggs is decomposing food waste (of animal or vegetable origin) that is moist but not wet. The eggs hatch to release white maggots, which feed on the waste. When mature, the maggots leave the waste and burrow down up to 60 cm into dry, loose soil, where they undergo the next stage as a pupa. The pupa looks like an oval brown seed about 6 mm long. The adult fly emerges from the "puparium" after a few days, finds its way to the surface and expands its wings before flying off.

Houseflies visit excreta and bring pathogens into kitchens on their hairy legs and bodies. They also spread disease (particularly diarrhoeal diseases) by vomiting and excreting on food. (Diarrhoea is a major cause of infant mortality).

The following table indicates how the duration of the life cycle depends on temperature. At optimum temperatures the maggots may leave the waste after less than four days and adults can emerge less than 6 days after eggs are laid. Because of decomposition, the temperature within a mass of waste can be higher than the ambient temperature.

	Average duration of different stages (days)		
Temperature	16°C	25°C	35°C
Egg	1.7	0.66	0.33
Larva (maggot)	11–26	6.5	3.5
Pupa	18–23	6.7	4
Mean total	32	11	6

Source: [Busvine, 1982]

tion that environmental issues are vital and in the public interest. Penalties should be high enough to motivate compliance and should be administered in an effective way by a judiciary that is convinced of the need to penalise environmental crime. All of these factors vary from place to place, and where there are deficiencies in this aspect, waste collection suffers, in terms of both the usage of containers and the payment of charges. An example is the often-quoted "polluter pays" principle, which states that generators should pay for the removal and disposal of their wastes according to their quantity and the difficulty of disposing of them in a satisfactory way. Although this principle is just and rational, it needs good enforcement or a high degree of universal environmental awareness, otherwise generators of large quantities of waste or difficult wastes simply avoid the charges by dumping their wastes illegally. For this reason the "polluter pays" principle cannot yet be applied effectively in many countries.

2.2.4 Conclusion

Many of these factors underlie the arguments found in subsequent sections, as their impact on the selection of equipment and the design of collection systems is discussed. The key lesson from this section is that there is no ideal solution that should be recommended for all countries, all the cities within a country or even all districts within a city. It is necessary to start the design process from the beginning, to "go back to first principles", and to make decisions based on local investigations.

2.3 PARTICULAR DIFFICULTIES FACED IN DEVELOPING COUNTRIES

2.3.1 What are the problems?

Solid waste management is one of the most difficult environmental problems in the urban centres of developing countries, where services are often grossly deficient, especially within low-income settlements. Often these settlements comprise a sizable proportion of the city's area and population – as much as half in some cases. Rapid urban growth, accompanied by the increasing density of population, traffic congestion, air and water pollution, increasing per capita generation of solid waste and the lack of land conveniently situated for waste disposal, all point to a rapid further aggravation of the already acute problems of solid waste management. Future demands are certain to increase as cities' residential, commercial and industrial sectors expand and as economies develop.

In many cities in the developing world, it is not uncommon to find that less than one third of the wastes generated in urban areas are collected by the municipal authorities entrusted with their disposal. For example, the proportion of waste that was collected in Dar es Salaam in Tanzania had dropped to less than 5% in 1992 before an emergency clean-up of the city was initiated under the UN Sustainable Cities Programme. By 2003 it had been increased to an estimated 32%[7]

Whilst the proportion of waste collected in the major cities may be more than 50%, in smaller provincial towns the figure is likely to be much lower. Almost invariably the high-density low-income housing areas are neglected or inadequately served, and these areas have a greater need for the service since they are less able to make their own arrangements for getting rid of their waste and the high housing density allows no space for burying or composting the waste.

In the absence of a regular solid waste collection service, waste is dumped in open spaces, on access roads and along watercourses. Dumps are invaded by waste pickers and animals which scatter the wastes, and the wastes serve as breeding grounds for disease vectors, primarily flies and rats. Leachate from decomposing garbage percolates into soil and nearby water sources, and the resultant contamination of food, water and soil can have serious environmental consequences. Uncollected refuse also finds its way into open drains; which become blocked, and the dammed-up stagnant water encourages the breeding of mosquitoes resulting in turn in many cases of malaria and dengue fever.

Many authorities which provide a solid waste management service suffer from frequent breakdowns of collection vehicles, and it is not uncommon for 60 per cent of the vehicle fleet or even more to be unserviceable at any time. Excessively high downtimes are often exacerbated by slow rates of repair and the resulting delays in returning vehicles to service. In one case in Tanzania, for example, small repairs took up to one week, and large repairs anything up to one month to complete[8], provided that the parts were available. It is not uncommon for vehicles to be out of service for many months awaiting the finance for the purchase of spare parts which may have to be imported from overseas.

The serviceable vehicles in many cities often carry small loads – frequently less than half their potential payloads – because their bodies are inappropriate. A single round trip can take as much as three hours to complete. Efficiency

7. *Reference [Chinamo, 2003]*
8. *Reference [Ngainayo, 1986]*

and productivity are both low, and service is commonly irregular. Irregularity leads to complete loss of rapport and trust between authorities and public, and in such cases, little, if any, co-operation can be mustered from the public to support the service.

A variety of financial, institutional, technical and social reasons are responsible for the low level of coverage and the poor service that is common in many urban centres in developing countries. The remainder of Section 2.3 suggests reasons for the shortcomings in solid waste collection services.

2.3.2 Inadequate resource mobilisation

General municipal revenue, raised by means of municipal taxes which are normally assessed on the size or value of the property being served, is the usual source of funds for the operation of solid waste management services. Municipal tax collection systems are inadequately and poorly administered in many countries, and insufficient funds are therefore made available to provide an adequate level of service. Informal or squatter urban communities, because of their informal status, pay no municipal taxes, and this fact has often been used as the principal argument against providing these communities with municipal services. The issuance of land title deeds or, at least, a declared intention to provide titles, is necessary before municipal revenues can be derived from these communities. It is often assumed that squatter communities are unable or unwilling to pay for urban services. However, experiences in Brazil, Indonesia, Sri Lanka and elsewhere increasingly indicate that these communities often consider the payment of municipal taxes and service charges to be a positive means of obtaining governmental recognition of their right to occupy their plots and a fundamental way of being integrated into the overall processes of the urban economy.

2.3.3 Over-reliance on imported equipment

In developing countries, the municipal income base from which revenues are derived is much lower than in industrialised countries; often only one fiftieth to one twentieth of the base available in industrialised countries[9]. Yet the cost of imported equipment and vehicles is generally higher in developing countries than in the industrialised countries in which they are manufactured. Although waste generation rates in developing countries may only be one third to one half of those in industrialised countries, it is evident that the best strategy for improved solid waste collection includes labour-intensive methods, increased local capacity in manufacturing and operating, and improvement of municipal finance.

The proportion of external funds to national funds for capital investments remains high. The foreign exchange component of costs of a solid waste project can amount to more than a half of the total costs. However, heavy reliance on external funding, inevitable as it may seem if progress is to be achieved in the short term, is unlikely to be a prescription for sustainable development and must be supported with sufficient levels of internal fund generation. The foreign exchange component serves as a useful indicator of the extent to which indigenous technology is used. Solid waste management projects that were initially heavily reliant on external funding or foreign exchange have encountered problems in obtaining continued sources of foreign exchange to operate and maintain assets. Box 2.2 describes one particular problem that resulted from an excessive reliance on imported technology. The use of labour-intensive, indigenous technologies has, however, enabled the foreign exchange component of solid waste management projects to be significantly reduced – to a mere 18 per cent in one case[10], This indicates the general direction that must be followed if self-sustaining waste collection systems are to become common.

9. Reference: [Cointreau, 1982]

10. Reference [Cook, 1977]

Box 2.2 | Example

The wrong size

Some years ago in an African country, a local authority had been provided with a number of refuse collection vehicles under an aid programme. Within less than three years the authority was advertising for the purchase of more trucks. When the author visited the municipal workshops he found three generations of broken-down trucks, all of which were awaiting spare parts. The latest batch of trucks was fitted with an unusual size of tyre, and as tyres were manufactured in the country concerned, there was a restriction on the importation of tyres to protect the local manufacturer. Before the vehicle manager could obtain an import licence he was obliged to obtain formal letters from all the tyre manufacturers to state that they could not provide tyres of the required size. Unfortunately he had been unable to obtain these letters so the trucks had been abandoned and the city waste collection service had collapsed.

As it happened, the author was able to show how to modify the wheels by cannibalising parts from previous trucks so that a locally available tyre size could be used. (Technically these trucks were no longer legal on the roads as the tyre size did not comply with the original type approval for that model of truck).

2.3.4 Inappropriate methods of finance

Refuse collection equipment has a short life; the useful life of a refuse vehicle is often no more than five to seven years, and may even be as low as three years. Even so, many developing countries finance refuse collection equipment by loans from bilateral or international lending agencies, on medium-term and long-term financing, without ensuring that adequate internal revenue will be raised for debt servicing, operation, maintenance and asset replacement. In one African country, for example, a fleet of new refuse vehicles was supplied under a 20 year soft loan including a five-year moratorium[11] on capital repayment. Failure to assess thoroughly the revenue generating capacity of municipalities and their debt-servicing requirements has left many without prospects for adequately operating, maintaining or replacing equipment.

Tied aid[12] and contractual credit from bilateral sources and private companies to supply specific, often sophisticated, refuse collection equipment have led some governments into accepting equipment without regard to its appropriateness. Box 2.3 mentions three examples.

Many foreign aid programmes associated with managing solid wastes in developing countries have as an objective the capturing of markets for supplying sophisticated machinery and the associated spare parts. Consequently, the trend has been to supply machinery developed elsewhere for entirely different conditions with little consideration of local conditions and the needs of the entire waste collection system.

Changes in aid policies can only be brought about through increasing the awareness of local decision-makers and donors alike regarding the principal issues involved in managing solid waste in developing countries.

11. *A moratorium on capital repayment means that there is no need to start repaying the actual sum that was borrowed until (in this case) year six. For the first five years only interest should be paid. It worth reflecting that the useful life of the vehicle may be little more than five years and that repayment of the loan used to buy vehicles may continue long after the vehicles have been scrapped.*
12. *Loans or grants provided by governments of industrialised countries with the condition that the money must be spent on goods or services supplied by the country that provided the finance.*

Box 2.3 Examples

No chance to choose

In one example, expensive refuse compactor trucks were donated for clearing high-density, water-soaked, abrasive refuse[1] from a city which had experienced a tsunami that had distributed solid wastes from dump sites evenly throughout the streets. Although the Government was not obliged to meet the cost of capital for the purchase of these vehicles, it did, however, have to pay for their operation and maintenance which, after a single year, would have amounted to almost as much as the initial capital cost of the vehicles.

In another example, before the consultants could arrive in an African country to study the problem of waste handling under an aid programme, the first machines had already been sent from Europe, with no apparent concern for the conclusions of the consultants' investigations.

In another case, the supply of short-lived refuse collection vehicles was included as part of a long-term infrastructural loan requiring "open international tendering" which resulted in the setting up of a sophisticated collection system which proved to be unaffordable and unsustainable in the longer term. The country concerned is still paying for these vehicles long after they have ceased working. Once a sophisticated system had been introduced it is extremely difficult to change back to a sustainable system.

1. *The reasons why compactor trucks are totally unsuited to collecting this type of waste will be explained in Section 7.1.4.*

2.3.5 Use of inappropriate technology

There are many reasons why it is essential to choose designs and technologies that are appropriate to the conditions where the machines will be working. Waste collection vehicles designed for one particular set of

Box 2.4 Example

Free trial

Two compactor trucks were provided to a developing country free of charge, with the understanding that the successful operation of the vehicles for a year would lead to the purchase of an additional 50 such trucks after this trial period. No attempt was, however, made to study the waste collection system as a whole, and no provision was made for developing a storage system that was compatible with the new trucks. (The existing method of storage was to keep the waste in large bins from which the waste had to be emptied onto the ground and shovelled into the vehicle.) The continued use of this method of storage and loading meant that the compactor truck took just as long to load as its predecessor – the ordinary roll-top truck – and the system demonstrated little improvement in productivity while requiring a significant increase in capital and operating costs. Furthermore the trial period would have proved too short to allow a detailed assessment of the long-term operation and maintenance requirements of the vehicles.

Box 2.5 Example

Good co-operation

There are also good experiences of international co-operation. One that is well-known to the authors and referred to elsewhere in this book involved one Asian nation providing the capital to a United Nations organisation for the purchase of trucks within the context of a project that was funded by a European nation. The trucks that were selected were manufactured in a different European nation and chosen because they were widely used in the particular area and so could be efficiently maintained. The bodies for the trucks were designed by an expert from a third European nation. The system has proved to be reliable and economical.

[Scheu, 2000]

conditions might be unsuited for another situation. The following examples illustrate this important point:

- Waste collection vehicles designed to handle a particular type of waste might be totally unsuited for waste with different characteristics. For example, vehicles which compact low density refuse to four times its original density are designed for the low-density wastes found in industrialised countries. Such vehicles are unsuited to use in most developing countries where the waste, in its natural state, is already very dense. Figure 2.1 shows typical compaction ratios for wastes of different densities. It shows that the volume of high density wastes (having a density of 400 kg/m^3) can be expected to be compacted to about 75% of their original volume by typical compaction mechanisms, whereas low density wastes (100 kg/m^3) may be reduced to less than 20% of their initial volume.

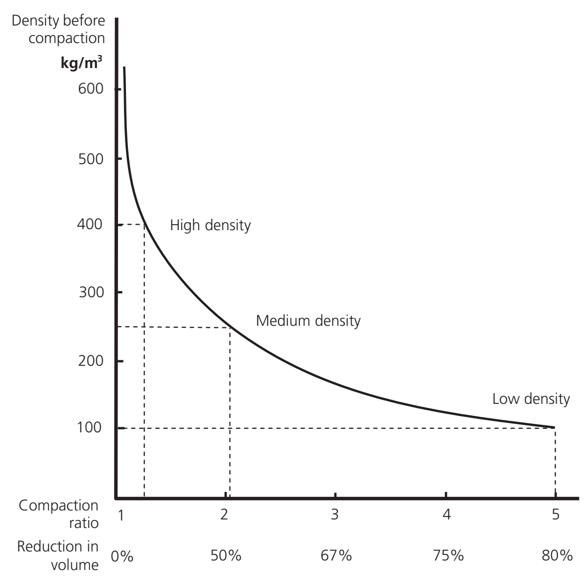


Figure 2.1 The reduction in volume that is achieved by a typical compaction mechanism for wastes of various densities
The precise values depend on both the nature of the waste and the design of the compaction mechanism.

- Waste collection vehicles that are designed to operate in spacious urban areas with well-paved roads might be totally unsuitable to serve high-density congested areas with poor access, although the two areas might be in the same city. There has been a trend to standardise collection fleets on a citywide basis, with the intention of promoting efficient maintenance and supervision, because all the vehicles are the same or similar. This trend has had the effect of excluding large areas of cities from receiving a service.
- Annual maintenance costs are usually between 5% and 10% of the purchase cost of a collection vehicle, and any savings in maintenance costs resulting from standardisation are unlikely to override the cost effectiveness benefits of using optimum collection methods which are designed specifically for particular conditions.
- In some instances, equipment may be considered to be inappropriate if it cannot be adequately maintained under the conditions in which it is operated. Equipment maintenance and resources allocated for this purpose are, in general, very inadequate in developing countries. The use of equipment that depends on imported spare parts for maintenance leads naturally to high maintenance expenses and. long “out-of-service” periods (or downtime). Inadequate maintenance is often identified as a principal cause of poor solid waste collection performance, and most maintenance problems are the result of the selection and use of inappropriate equipment.
- A system may be regarded as inappropriate if the balance between mechanisation (capital costs) and labour inputs is not suited to local conditions, leading to inefficient or costly waste collection services. For example, in many countries, waste collected in simple primary collection vehicles, such as handcarts, is often dumped on the ground, to be later picked up using a rake and basket for loading onto the trucks that provide the next stage of the transport process. This results in both labour wastage and excessive vehicle waiting time, in addition to exposing workers and public to health risks. In middle-income countries, a very thorough analysis is often necessary to determine the optimum level of mechanisation. However, in low-income developing countries, vehicle and fuel costs are high, while labour is cheap. In these cases, labour-intensive methods will no doubt optimise overall system cost-efficiency and vehicle productivity, provided that vehicles are not kept waiting for a long time while they are being loaded.
- Lack of appreciation of the socio-economic and cultural factors which determine behavioural responses from the public has led authorities to introduce systems which have proved inappropriate and ineffective. This is particularly important in connection with the selection and use of storage containers (Box 2.6 (c)).

Efficiency suffers if a vehicle continues to be used beyond its economic life, when maintenance costs and downtime become so high that it is cost-effective to replace the old

Box 2.6 Examples

Examples of inappropriate technology

a) Excluding many urban areas – In a Caribbean island, for example, foreign consultants developed proposals for a solid waste management service which could only be applied to areas with roads wider than 4 m and gradients flatter than 25 per cent, and so all urban areas where the streets did not meet these criteria were excluded from receiving a service, and this was. a significant proportion of the island. Vehicle standards based on the requirements of middle-income and high-income areas requirements are rarely suited to low-income areas.

b) Maintenance costs – One Latin American country introduced imported refuse collection vehicles which used a hydraulic ejection system for unloading. The hydraulic cylinder that operated the system cost US$ 4,000 and had to be replaced every 10 months due to the very abrasive ash and sand content in the wastes and the lack of appropriate wiper seals on the cylinders. This small component alone required an equivalent of US$ 80 per vehicle per week and a reliable supply of spare parts in order to keep the vehicle fleet in serviceable condition.

c) Culture and containers – A sophisticated system of waste collection was introduced into one Pacific island, utilizing special plastic bins and vehicles designed to handle these bins mechanically. The consultants who introduced the system had not appreciated that, in that country, a plastic bin was too valuable an item to be used for refuse. Instead residents used them for brewing beer, washing clothes, bathing children etc. The bins were, therefore, not used for their intended purpose, and the refuse collection vehicles were left standing idle; since they were not designed for manual loading of the wastes from 200 litre oil drums – the type of refuse container that was widely used throughout the country. In another case large numbers of plastic wheeled bins were stolen and even cut up for recycling.

vehicle with a new one. Ten years is often taken as the maximum period for which refuse collection vehicles should be used, but records of expenditures can be used to calculate more precisely when it is more economical to replace rather than to repair. Unfortunately it is often the case that vehicles are replaced only when external financing or transfers from central government are made available, so local managers are often not able to decide when a vehicle should be retired and replaced. A UNCHS (Habitat) study[13] of waste disposal practices in Peshawar, Pakistan, revealed that 85 per cent of the local municipal council's fleet was made up of vehicles that were more than 10 years old; some vehicles were even as old as 28 years. The continued use of vehicles beyond their economic life reduces overall system efficiency and financial performance.

2.3.6 Inequity in service provision

The urban poor have often been excluded from to the benefits of solid waste collection services. Even when a service is provided in poor areas, the level of service is usually much lower than that provided to middle-income and high-income areas. For example, one investigation revealed that, in one African city, only ten per cent of the waste generated in poor neighbourhoods was collected, as compared to 80 per cent in upper-income residential areas. Likewise, while a large squatter settlement, housing approximately 20 per cent of the total population of a city, was observed to have only five per cent of its waste collected by the municipality, the average for the whole city was 33 per cent. It is, however, evident that it is in low-income communities, where population densities are high and awareness of the hazards of uncontrolled refuse disposal is low, that the need for the service is greatest. The poor are often willing to pay for a waste collection service because it so difficult otherwise for them to get rid of their solid wastes.

There are several reasons for the poor levels of service usually observed in low-income communities. The majority of these communities pay no municipal taxes. Standardised refuse collection vehicles are too big to enter the unplanned areas where these communities live. Waste collection teams may also be reluctant to visit low-income areas because the waste in these areas has less recycling value and because the residents in these areas do not pay tips or offer refreshments or give presents at festival times. Since the majority of those who need to be provided with a solid waste management service in developing countries actually live in low-income communities, there is a need to overcome these constraints and develop collection systems and equipment which can be used effectively in these areas.

2.4 OBJECTIVES OF IMPROVED SOLID WASTE COLLECTION

The solution to many of the problems of solid waste management is the careful selection and operation of solid waste collection equipment that is efficient and yet responsive to the physical and socio-economic conditions of the various neighbourhoods in which service is supplied. The objectives of improved solid waste collection could, therefore, be defined as:

13. *[UNCHS, 1988]*

a) The system can operate sustainably within available financial resources.
b) Development and use of, as far as possible, relevant, efficient, indigenous equipment that requires the least expenditure for every ton collected. If the cost of collecting each ton (incorporating capital and operating costs including overheads) is kept to a minimum, it can be said that the subsidiary objectives of high productivity for labour and machines have also been achieved. Productivity is a useful performance measure that allows comparison with performances elsewhere. (This comparison is also known as benchmarking). High productivity requires the optimisation of labour and equipment requirements, and the minimisation of vehicle round-trip time and downtime. Even reliability and vehicle downtime can be included in the cost of collecting one ton (see calculations in Annex A3).
c) The collection service benefits from the co-operation and the approval of the citizens.

Providing a service that meets, as far as possible, the expectations of the citizens and yet can be afforded, is the concern of this book.

Summary points

- International differences – social, economic and geographic – have a major influence on the challenges posed by solid waste and the best ways of meeting these challenges.
- Strategies are needed to provide reliable solid waste collection services in the face of rapid urban growth and difficulties in serving unplanned urban areas.
- Mismanaged solid waste in urban areas causes serious environmental problems.
- A special effort is needed to extend adequate services to citizens in low-income areas.

3 WASTE QUANTITIES AND CHARACTERISTICS

This book is concerned with the collection of solid waste and touches only briefly on recycling and disposal. Some aspects of the characteristics of municipal solid wastes are not relevant to collection. Other books on solid waste management cover all the aspects of waste characteristics, including the analysis of the different waste constituents which is required for assessing the different recycling and treatment options and the methods of calculating the suitability of the wastes for composting, incineration and other processes. Guidance on conducting composition studies is not provided in this Chapter, because such studies are not considered relevant to the specification of storage and collection equipment.

For the purpose of selecting the optimum collection systems and vehicles, it is essential to know the quantities and densities of the wastes from the different parts of the particular city and also to note if there are significant quantities of abrasive materials (sand, clay and ash) and corrosive materials (biodegradable wastes which decompose to form acids) in the wastes which will effect the life and depreciation of the vehicles and of the containers that are used for storing the wastes.

3.1 SOURCES OF MUNICIPAL SOLID WASTE

- **Household waste** – In developing countries, up to two-thirds of this category consists of organic kitchen wastes. The balance is composed of sweepings, rags, paper and cardboard, a small but growing percentage of plastic, and small proportions of glass, rubber, leather, bone and metals. In poor neighbourhoods, traditional cooking can also produce ash, and where sanitation facilities are limited, the waste might also include faecal matter. In wealthy countries discarded furniture, used appliances and garden wastes are included.
- **Commercial waste** – In developing countries, markets are an important source of commercial waste, much of it biodegradable. Other sources include shops, offices, restaurants, warehouses and hotels. While some large offices or hotels arrange for private collection of their wastes, most of the commercial waste continues to be handled by municipal authorities. Shops often discard large numbers of cardboard boxes, which quickly fill communal waste containers unless the boxes are flattened or taken for recycling.
- **Institutional waste** – Solid wastes from schools, governmental offices, hospitals, and religious buildings are included in this category. Paper is the predominant waste from most institutional sources except those containing residences, such as barracks and nurses' hostels, where the proportion of food waste is significant. Wastes from hospitals and other healthcare establishments should be segregated into two main categories – hazardous and general. Only the non-hazardous (general) wastes are the responsibility of the municipal authorities. Waste collection from institutional premises often entails the use of a different collection method to that used for households because of the large quantities that are generated.
- **Street sweepings** – Street sweepings consist of sand, stones, spilled loads and debris from traffic accidents, as well as paper and plastic litter dropped by pedestrians and from vehicles or blown by the wind. They may also include appreciable amounts of household refuse and human and animal faecal matter.
- **Drain wastes** – In some cities the cleaning of open storm drains and culverts is linked to street sweeping. Silt from drains can be difficult to dislodge and is usually wet and very dense. Cleaning culverts requires special tools. Cities may organise drain cleaning campaigns just before the anticipated start of the rainy season.
- **Bulky waste** – This includes items that are too big to be collected by the normal system for collecting municipal waste, and are not generated on a regular basis. Examples are old and unwanted furniture, mattresses and household appliances, and sometimes the carcases of large animals. In many low-income countries old furniture and appliances are sold for repair or recycling rather than being discarded as waste. Discarded refrigerators and air-conditioners contain fluids (CFCs) which damage the protective ozone layer in the atmosphere, so these liquids should be removed from such discarded appliances, using special equipment, by the waste management agency before disposal.
- **Foliage** – Residues from gardening and pruning often have a very low bulk density, (unless they are shredded) and so can occupy large volumes in storage containers

and collection vehicles. In many climates large quantities of such wastes are generated seasonally or after violent storms.

- **Unwanted vehicle scrap** – In low-income countries scrapped motor vehicles are generally recycled as much as possible, and so they do not represent a waste management problem. However, in some middle-income countries there may be significant amounts of vehicle scrap abandoned in public places. The police are normally involved to warn the owner of a car that appears to be abandoned before it is removed.
- **Hazardous household waste** – In many countries, provisions for separate collection of hazardous household wastes are not yet being made. Hazardous household wastes include residues of toxic chemicals such as paints, solvents and some cleaning agents, batteries (both dry cells and lead-acid accumulators from vehicles), unwanted medicines, used hypodermic syringes, fluorescent tubes and discarded electronic equipment. Before such wastes can be collected separately it is necessary to have legislation requiring this service, a means of disposing of these wastes that causes less environmental damage than the current system (which is generally dumping them together with general municipal wastes), and a large public awareness campaign to make citizens convinced of the need to segregate such wastes, and aware of the collection arrangements for these wastes.
- **Special printed paper** – Very small quantities of printed paper may need special arrangements for collection and disposal because of their confidential or religious nature. Confidential wastes may include bank and medical records, as well as other documents that should be destroyed rather than recycled. In some Muslim countries there may be a demand for a special collection service for paper on which words from the Koran are printed.
- **Construction debris** – Construction and demolition activities generate a variety of residual building materials, as well as soil and rock from excavation which can contribute significantly to total waste quantities. In the absence of adequate local by-laws, the municipality is assumed to be responsible for the removal and disposal of these wastes from small house repairs and modifications. Wastes from larger projects should be the responsibility of the builder. Construction wastes differ considerably from household wastes, and alternative heavy-duty vehicles and equipment are used to collect them. Some local authorities will provide a service for these wastes at a separate charge per truckload.
- **Industrial waste** – Industrial wastes from processing and non-processing industries and utilities are generated in quantities and with characteristics that are directly related to the size and number of the industries and their nature. Packaging materials; food wastes; scrap metal, plastic, and textiles; fuel-burning residues; and spent process chemicals are among the wastes in this category. Small-scale and cottage industries tend to dump their unrecyclable waste in the containers for general municipal waste, while large industries usually contract for private collection and disposal. Some municipalities offer a special fee-paying service to industries. A small proportion of industrial wastes can be classified as hazardous and so should be subject to special procedures for transport, treatment and disposal, but lack of specific legislation or poor enforcement of legal requirements often allow the hazardous wastes to be handled and disposed in the same way as non-hazardous industrial wastes.
- **Overview** – From the foregoing urban waste classifications, it is evident that different categories of waste may require different handling, collection and disposal equipment. In terms of proportions, household waste accounts for usually up to 75 per cent of all the municipal solid wastes. (These figures exclude construction and demolition waste, which varies greatly in quantity, depending on the amount of construction work that is being undertaken.) Emphasis in this book has been given to the four categories of waste that comprise the largest proportions, namely household, commercial, institutional and street wastes, which together are termed municipal solid wastes. Small quantities of construction and demolition debris are often generated by refurbishment or small alterations in houses, and these wastes are often mixed with household wastes, sometimes causing significant problems because their density is so much more than household waste. At the other extreme, waste from tree pruning usually has a very low bulk density and occupies large volumes. Nonetheless, most of the basic principles discussed in the report apply to all the various kinds of waste that may need to be collected. Although municipal solid waste may make up most of the waste that needs to be collected, attention should also be given to these other types, to make sure that there are suitable ways of collecting them also.

3.2 OBTAINING DATA CONCERNING THE WASTE

3.2.1 Generation rate

The generation rate is the amount of waste generated by one person, one household (or one appropriate unit[14] for other types of generator) in one day. Usually it is expressed in terms of weight. The per capita generation rate, when multiplied by the population served, gives an indication of the total amount of waste to be collected and disposed. Unfortunately there are many reasons why available data on generation rates are unreliable. This section suggests some reasons why quoted values of generation rates are often misleading; knowing the reasons for errors in such data is the first step towards obtaining useful figures and understanding the degree of confidence that can be placed in them. It also offers some recommendations regarding collection of waste generation data.

It is generally not possible to obtain reliable information as to the waste quantities and densities in any situation without making field measurements. Local authority staff are rarely able to give reliable information about how much waste is generated in any particular area unless the authority has a weighbridge at the disposal site. There are two main reasons for this:

There is a tendency to greatly overestimate the amount of wastes generated and collected. Often the local officials involved use the nominal load capacity of a truck (in tons) and multiply it by the number of truck loads instead of using the truck's volumetric capacity. This can readily be illustrated by an example. A typical 7 ton tipping truck with a 6 m^3 capacity body collecting wastes whose densities average 350 kg/m^3 can carry only 2.1 tons of waste on each trip – not 7 tons – because the size of the load in such cases is limited by the volume of the truck body not the maximum weight that the truck is able to carry.

Truck drivers tend to report the maximum number of loads collected in a good day rather than the average number of loads over a period of several weeks. They may therefore claim to collect three loads each day when in fact the average is only two due to slow loading times and other delays.

Taking only the above two factors into account and using the examples given, it can be seen that the waste quantity collected by one truck may be quoted as 7 x 3 = 21 tons/day based on the nominal capacity of the truck and the peak number of loads, whereas the actual amount collected is only 2.1 x 2 = 4.2 tons/day, showing that the quantity may be overestimated by 500%.

This simple example and the experience recorded in Box 3.1 show why it is essential that only confirmed data are used for any study, unless a weighbridge is in use and data are being recorded consistently. As a general rule, it is unwise to accept data that have a significant impact on the choices that will be made unless it is possible to discover in some detail how the data were collected, and one is satisfied that the method of collection was satisfactory and that the results are relevant.

Estimates of waste generation rates vary according to where the waste is measured or weighed. For example, studies in East Africa indicated that the amount (volume or weight) of waste that was available for collection was less that the amount generated by the households for a number of reasons, including:

- Some of the food waste is fed to animals;
- Evaporation of moisture during storage;
- Burning of wastes for fuel and for disposal;
- Decomposition of organic wastes;
- Selling of reusable materials and items to itinerant waste buyers;
- Waste picking at the communal containers;
- Scavenging by animals at the containers;
- Scattering of wastes by animals and waste pickers;
- Blowing of wastes by the wind.

Generation rates measured at households may therefore overestimate the quantities that require collection and disposal, as suggested in Box 3.1. It is common to quote estimates of the collection efficiency – the percentage of generated waste that is collected – as an indication of the success of the waste collection service. If the total amount of waste to be collected is overestimated, the estimate of the collection efficiency that is based on this estimate will be too low.

14. *"Appropriate units" could be beds for hotels and hospitals (so generation rates would be expressed in kg/bed.day) or units of output or tons of material processed in the case of an industry.*

Box 3.1 Example

Uncertainty about total waste quantity

In one particular African city, when the city council's solid waste management system had almost completely broken down, it was estimated by a consultancy study that the city was generating 1,400 tons of wastes per day. However, as the collection system was being improved, it was found that when the collection capacity had reached 400 tons per day there was very little waste left in the city – apart from some peripheral areas where waste was buried on-site. This suggests that studies based on household surveys may greatly overestimate the amount of waste that needs be collected. Such differences may be due to on-site disposal, recycling, feeding waste to animals, or inaccuracies in the household survey methodology.

a) Estimating generation rates at household level – A common method of estimating generation rates is to weigh the waste that is generated by a sample of the houses and shops in a city or district. This requires collecting waste from selected sources, keeping a record of the number of dwellings or shops that are providing the waste, knowing the number of days since the waste was previously collected, and weighing the total amount of waste collected. If a per capita generation rate is required, the number of people living in each contributing household must also be ascertained. In doing this, the following points should be kept in mind.

- Different groups of generators should be distinguished. Residents of different socio-economic groupings generate waste at different rates, and shops, offices, institutions and small factories may generate significant quantities of waste. The relative proportions of each group should be known for the particular urban area.
- Wastes may be collected from households and businesses without informing the residents or in a way that requires their co-operation. An example of the latter approach is the distribution of plastic bags into which residents and employees are asked to put the waste each day. Some residents may put extra waste into the bags (if this "collection service" is more convenient than the usual service, so that they clean yards and poultry houses and get rid of unwanted vegetation) while others may put less waste into the bags than usual (because they are worried that their waste will be examined or that large quantities of waste will lead to extra taxation). Both of these behaviours can seriously distort the final results.
- Waste generation varies with day of the week and with season, so an accurate study must take this into account.
- Samples should be selected carefully so that they are representative.
- Studies that aim to estimate waste generation may take a considerable amount of time and require the payment of considerable fees for consultant time. The design of such studies should be considered carefully with regard to the need for the data and the required reliability of the final figures.

b) Measuring at the disposal site – Weights of the waste reaching the disposal site can be used to calculate generation rates if the number of people generating the waste is known.

If a weighbridge is not available at the disposal site, it may be possible to use a public weighbridge or one belonging to a local company (such as a concrete or asphalt plant) or other organisation for weighing random sample loads or for periodic weighing programmes. If no weighbridge is available, it is often possible to borrow portable axle load scales from a university, other research organisation or road testing station. These wheel scales are very portable and can be carried in the boot (trunk) of an ordinary saloon car. They are not very costly and could be purchased as part of the facilities and equipment provided for a waste management study project. Typically, maximum rear axle loads for a single rear axle (4 x 2) truck are 12,000 kg and so two weighing scales of 8,000 kg capacity each would be sufficient for weighing one axle at a time. Four scales would enable the front and rear axles to be weighed at the same time. If twin rear axle (6 x 4) trucks are used, four scales would be required since both rear axles should be weighed together.

When this information has been obtained, the most effective way of estimating the number of people contributing the wastes may be to ask all the people concerned what percentage of the total waste generated they think is being collected. Alternatively it may be possible to estimate the proportion of the urban population that receives a waste collection service by adding the populations of the areas and districts that are served and referring to the collection routes of the vehicles. A tour of the city on a street-by-street basis may help to confirm these estimates.

In geeral, when proposing the introduction of new collection vehicles and storage systems, it is recommended that new equipment should be phased in over a period of a few years to ensure that the vehicles do not all become obsolete at the same time in the future. It can then be recommended that the numbers of vehicles and containers required can be reviewed each year in line with any new data becoming available. This progressive and flexible approach does not depend so heavily on getting initial accurate data for waste generation, since the numbers and locations of containers and the numbers of trucks can be adjusted in line with more accurate data as they become available from the monitoring of operations. Unfortunately this flexible and phased approach is often not possible in the context of donor or development bank projects.

3.2.2 Waste density

For most purposes relating to the collection of wastes, it is necessary to know the volume of the wastes rather than their weight. Perhaps even more important is the density[15], which enables the conversion of weights into volumes and vice versa. As discussed above, it is generally possible to find a way of weighing vehicles, even if there is no weighbridge at the disposal site. By estimating the volume of randomly selected loads (by measuring the dimensions of the body carrying the waste and making a judgement as to how completely it is filled) and weighing the vehicle loaded and unloaded a reasonable estimate of waste densities can be obtained. If no weighbridge is available, it may be possible to measure the density of the waste in the storage containers or when tipped into a larger box, by weighing the container or box full and empty and by making a correction for density variations according to the nomograph in Figure 7.3 in Section 7.1.2. With some practice and quite a lot of experience, a waste management consultant should then be able to estimate waste quantities reasonably accurately by recording the number and the volume of the loads arriving at the disposal site. In many cases, data obtained in this way are likely to be much more accurate than the information provided by local authorities. Box 3.2 recounts an experience in connection with waste density that shows how careless some experts can be.

It must also be recognised that waste density varies considerably during handling, having different values in the initial storage container, in the truck body after loading, and again in the truck body after transfer or after the wastes have shaken down during the journey to the disposal site. Waste in containers gradually compacts over several days as a result of the weight of the waste itself, the softening by moisture of paper packaging and the decomposition of biodegradable wastes.

When estimating the number and capacity of the vehicles required for collection, the density that should be used is the density of the waste after loading into the

15. *Density is the weight per unit volume (usually one cubic metre) of the material, and is usually expressed in kg/m³*

Box 3.2 Example

Waste densities – Where did the data come from?

Some years ago the author was asked by one of the world's leading lending agencies to undertake a review mission for a solid waste management project in a Middle Eastern country where American and European consultants had combined to carry out a study for the solid waste collection of the capital city. This study was in preparation for a major waste management loan to the city.

The consultants had proposed a system using rear-loading compactor trucks with hydraulically operated binlifts to pick up wheeled containers to which the citizens would bring their own household and commercial wastes. The containers would be located on the many patches of waste ground throughout the city.

A quick glance around the city showed that:

- The municipal waste densities in this city were extremely high due to the amount of sand blowing in from the desert areas. Based on these observations, the reviewer estimated the average waste density to be about 600 kg/m³, with occasional loads as high as 800 kg/m³.
- The areas of waste ground where it was proposed to locate the containers consisted of patches of soft sand with some construction wastes.
- The trucks and the containers proposed were designed for use in European cities where the roads had smooth, hard surfaces and the density of the wastes was low. The small wheels supporting the containers were not intended for use on soft sand.

It was immediately apparent that the chosen trucks would be enormously overloaded, the compaction mechanisms would wear out very rapidly because of the high content of abrasive sand, the lifting mechanisms on the trucks would not be able to lift some of the heavier containers and it would be impossible to wheel the containers to the trucks over the soft sand and construction rubble. In other words the system simply could not work under the local conditions.

On questioning the consultants it was found that they had based all their calculations on a waste density of around 250 kg/m³ whereas the reviewer was estimating more than twice this density, so an investigation was made to identify the source of the data. It was found that:

- The consultants had taken their data from a previous study which had been carried out a few years before by a European consultant.
- The previous study had taken their data from yet another study which had been carried out perhaps fifteen years before by a different European consultant.
- This earlier study had used data from a student's studies into household waste densities for his Masters thesis about 20 years previously in an adjoining country which did not even specify at what stage in the collection process the waste densities had been measured.

In summary: the data used for this study was based on data collected for a different country and city, did not specify whether it was measured at the house, in community containers or in the trucks and was already 20 years out of date. The system proposed would have involved a major investment in trucks and containers and simply could not have worked in the city concerned. These findings of the reviewer were not welcomed by the lending agency, the consultants or the anticipated suppliers of the trucks and containers, and the reviewer was not popular when he insisted that the consultants should obtain reliable and relevant density data and then redesign the system.

truck. This density should be calculated by measuring the volume occupied by the wastes at the end of the collection round but before the journey to the disposal or treatment location, because the volume is likely to be reduced by the vibration caused by travelling. The load may be weighed at the disposal site since the weight of the load will not change during the journey to the disposal site. Work study measurements of the loading and travel times (Annex A1) will provide other data required for calculating future vehicle requirements. For estimating the required capacity of community containers, for example, the weight and volume of wastes in containers should be measured when the container is nearly full, after a time interval that is approaching the interval between collections. Transfer station capacities should be estimated using the actual density of the wastes in the transfer containers or vehicles after the collection vehicles have discharged their loads into them. (An allowance must be made for some increase in density which will take place due to the self weight of the wastes in high-sided containers). It is always important to make a number of readings to understand the variation that can be expected, and it may not always be appropriate to use averages – for example when determining the required size for small containers it may be appropriate to use a density value near the lower end of the range of the values measured, and if concerned about the weight of a container that must be lifted manually when full, a density near the top of the measured range should be used. For considerations involving large volumes of waste (such as truckloads) seasonal averages are suitable.

Figure 3.1 shows the results of a survey of a particular area in Pakistan where it can be seen that the waste density at the household was only just over one half (54%) of that in communal containers. This means that the volume of the household wastes in the containers should have been one half that of the volume at the household.

Figure 3.1 also shows that in the Pakistan study the density of the wastes in the collection vehicles had reduced by around 20% during loading in to the refuse trucks. This is due to entrainment of air during the loading process and the method of loading used will have a considerable effect on the final density in the trucks. If the wastes are forked into the trucks there will be a large amount of air entrainment. If however the wastes are passed up in buckets, bins or trays there will be less air entrainment. These observations are generalised in Figure 7.3 in Section 7.1.2.

The result of all these changes is that it has been found that surveys that measure density at the household are of very little value in determining the volume and density of the wastes for sizing the collection vehicles. So what are the alternatives?

Regular weighing in the different seasons and estimates of the volumes of the loads provide a considerable amount of information, leading to sufficiently accurate volume and density data for the different types of trucks.

Many waste collection systems use hydraulic compaction to increase the density of the waste in order to reduce vehicle and storage requirements. The percentage reduction of volume that is achieved by a particular mechanism working at a particular pressure depends very much on the nature of the waste. As shown in Figure 2.1,

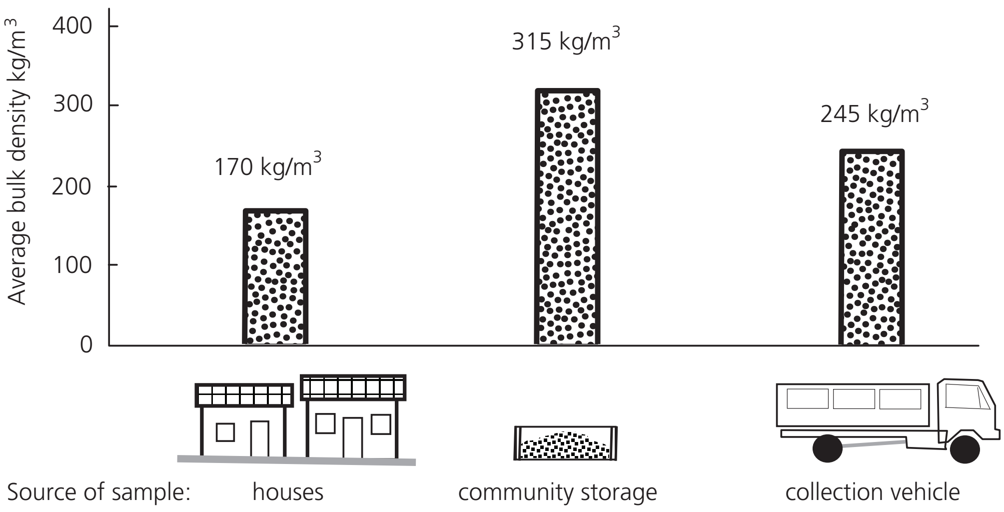


Figure 3.1 Variations of waste density between the household, in the community container and in the transfer vehicle for a typical situation in Karachi, Pakistan.

the volume of mixed municipal waste in an industrialised country may be reduced to 25% of its initial volume (that is, a compaction ration of 4 : 1) by a particular compaction mechanism, but the reduction achieved by the same mechanism may be to only 70% (1.4 : 1) with denser waste in a developing country.

It is therefore essential for the selection of any waste storage, collection and transfer system to use reliable information on both the weight of the wastes and the volume they occupy at the different stages between storage and final disposal.

In the industrialised countries refuse contains a considerable quantity of packaging materials, which occupy large volumes but are light in weight. Consequently, refuse in industrialised countries usually has a low density, typically ranging between 100 and 150 kg/m^3. The waste in developing countries is naturally dense, with densities typically ranging between 300 and 600 kg/m^3. (In an extreme situation in Gaza, Palestine, a waste density of 1,040 kg/m^3 was measured in a truck body.) The much higher densities in developing countries are often caused by higher moisture contents, more fruit and vegetable waste, higher proportions of sand and soil, and lower quantities of paper and packaging.

In the previous version of this UN-HABITAT publication – *Refuse Collection Vehicles for Developing Countries* – a chart was included (Table 3 *Typical Density Range of Municipal Solid Wastes*) listing the densities of the wastes from several industrialised, middle-income and low-income countries. These data were collected from a number of different sources but in most cases no information was available as to where and how the data had been collected. In a typical city the waste generation rate in a low-income area may be less than one half the average waste generation rate for the city as a whole and the waste densities vary greatly between low- and high-income areas. Thus the waste densities are higher and the daily waste generation rates in kg/capita are lower in a low-income area, resulting in a difference of as much as four times in the volumes of wastes generated by one person in the different districts of the same city, requiring different approaches to storage and collection. These factors were all mentioned in the text of the initial publication but, despite these warnings about differences, it has become apparent that the average figures shown in that table have frequently been used by consultants and local authority officials as reliable figures that apply to a whole city, without any further studies being undertaken. Waste density figures in particular have been taken from a study for one part of a country or city and used for very different parts of the same country or even for an adjoining country without any consideration of their relevance or accuracy. These figures have then been used to justify the choice of the system to be used and to justify large capital investments in equipment.

For this reason, in this second edition, it has been decided not to include examples of waste densities from different countries but just to describe general trends between industrialised, middle-income and low-income countries. It is essential that studies are carried out in each location or that well-informed estimates are used before any decisions relating to waste storage, collection or transfer are made and that only these primary data are used for selecting systems and equipment.

Waste densities and quantities can change with time, differing according to location and socio-economic factors. Changes in the types of packaging of food and drinks, and the introduction of a deposit system for drinks cans are two examples of factors that may cause a relatively rapid change in waste densities. The following basic data concerning the waste itself are required when making any design decisions concerning waste collection and transfer systems:

- The average weight of wastes produced each day per capita or per household (generation rate) in the area to be serviced, and population data for the different parts of the area to be studied to enable estimation of the weight of wastes to be collected each day.
- The average density of the wastes after loading into the collection vehicle. This, combined with the generation rate, will determine the volume of waste to be collected each day and whether compactor trucks or non-compaction vehicles are appropriate.
- The presence of significant quantities of biodegradable organic wastes will influence the maximum length of time between collections so as to avoid insect problems, smells and corrosion problems in containers and trucks as organic wastes decompose and form acids. A visual inspection of waste from all types of sources is sufficient.
- The inert content of the wastes (sand, clay and ash) will determine whether there will be a problem with abrasive wear on compaction type vehicles. The presence of hot ash in the waste indicates that plastic containers should not be used. If information about the use of solid fuels and the internal paving[16] of houses is

16. As discussed in Section 2.2.1, sand and soil can be expected in the waste if yards and floors are not covered, paved or sealed in some way.

not available, samples of waste can be sieved to determine whether ash and sand are present in significant quantities. Street sweepings may be seen to contain significant quantities of fine sand.
- If there are significant quantities of other types of waste in the area being considered – such as market waste or office waste – estimates of density and quantities of these wastes are also needed.

A wide range of additional data related to available space for storage, traffic movements and distances is needed before a collection system can be designed, but reliable estimates for the waste quantity and density are an essential starting point.

It is not necessary to carry out a detailed analysis of the constituents of solid wastes for the purposes of choosing the optimum collection and transport system. However, the national environmental agency in each country should be encouraged to develop a database of waste characteristics throughout the country which could be used for selecting the optimum recycling and treatment options.

Summary points

- There are many sources and types of solid waste, some requiring special methods of collection.
- For designing solid waste collection systems, the most important waste parameter is the density of the waste. Daily waste quantities should also be known with some accuracy.
- Even without the use of compacting machinery, the density of a sample of solid waste can vary considerably through the stages of storage and collection.
- Readily available data are often unreliable.

4 METHODS OF WASTE COLLECTION

4.1 INTRODUCTION

The collection system must be designed and operated in an integrated way. This means that all of the links in the management chain should be considered when any part of the system is being designed, so that all system components are compatible. For example, the method of loading a collection truck must suit the containers that are used to store the waste. As another example: if waste is to be recycled, the collection stage should be designed so that there is the minimum degree of contamination of the material destined for recycling. Again, if waste is to be deposited at a landfill, the trucks that take it there must be suitable for driving on the landfill. Because of this interrelationship between the different stages, this chapter, which looks at the general and overall aspects, precedes the chapters that consider the selection and use of equipment for the various individual stages in more detail. First the general objectives and requirements are set, and then the different components can be selected or designed, taking into consideration how one stage is influenced by the preceding stage and will influence the following stages.

This chapter first considers timing of the collection of the waste. It then considers the point of collection – where the waste is transferred from the custody (or responsibility) of the generator to the equipment of the collection agency. This is followed by a general discussion of the methods used to load and transport the waste to the next stage, whether treatment or disposal. In other words; when, where and how.

4.2 TIMING OF COLLECTION

4.2.1 Frequency of collection

The frequency of collection (in terms of the number of times in a week or a month that waste is collected) is a fundamental parameter of any waste collection system.

Some of the factors that should influence the frequency of the service (public expectations, fly breeding and decomposition) have already been discussed in Section 2.2. In general the frequency of collection must be higher in developing countries than in temperate industrialised countries, and the frequency must be acceptable to the residents, otherwise waste may be dumped in the streets. Residents are generally less concerned about the frequency of collection from community or shared storage points or containers, but if the wastes are allowed to accumulate in the street in large quantities, local people may set fire to the waste, causing harmful and unpleasant local air pollution.

Cost is another factor that should be considered, since it is more expensive to collect smaller quantities of waste on more occasions, though the extra cost may not be so high in the case of primary collection with simple equipment where wage levels are low. More frequent collection allows the use of smaller containers, which could be a significant benefit if waste generators are required to carry their waste to a collection point at a particular frequency. It may be that the freshness of biodegradable waste is a factor to consider if the waste is used to feed animals and to reduce odours at the input end of a compost plant. Leaving waste in steel containers for longer periods may result in faster corrosion of the containers because the initial decomposition of organic materials produces acids which attack metals.

A further point relating to frequency is the issue of reliability. It is very desirable that the frequency does not vary, so that householders and shopkeepers know when their waste will be collected. Small adjustments to collection frequency may be needed because of public holidays, and it is important that generators are informed of these changes in advance. Unexpected fluctuations in frequency undermine confidence in the waste collection service and in municipal management.

4.2.2 Time of day

Whilst waste collection from urban areas is normally carried out during the hours of daylight, there are many instances of waste being collected at night. In large, congested cities at least some of the collection operations may be carried out at night in order to avoid the traffic congestion that blocks many roads during daylight hours, greatly increasing journey times and reducing productivity. Waste collection vehicles themselves cause congestion, particularly if they must stop in narrow streets. There may also be regulations that prevent trucks from using city streets during business hours, to reduce congestion.

In some small cities and towns waste has been collected, and perhaps is still being collected, at night, for reasons that are not clear. Perhaps the reasons that influenced the decision to collect at night include the following:

- Waste is collected in the big cities at night because of traffic congestion, and the smaller cities and towns do the same because of national policy.
- Shopkeepers and residents are accustomed to putting their waste out for collection in the evening, after the close of business and after the last meal has been prepared, and therefore the waste is collected at night so that no waste is left for the next morning.
- Collection at night may be preferred by collection crews when daytime temperatures are very high and the sun is very strong.
- Waste collection is considered to be an unpleasant occupation that should not be seen, or waste workers wish to remain anonymous.

Collection at night suffers from several disadvantages, including:

- Collection vehicles can be noisy, especially compactor trucks. Residents may object to collection operations at night, when they are trying to sleep.
- Loading waste and sweeping streets can be difficult and even dangerous at night in places where there is inadequate lighting, and female workers may be reluctant to work at night because of fears of harassment.
- Collection at night may require the operation of landfills at night, which may be difficult if there is inadequate lighting at the landfill. Site managers may be needed both day and night. The risks of accidents may be higher at night, especially if pickers are sorting through the freshly dumped waste.
- Supervision may be less effective.

4.2.3 Shift working

Many waste collection agencies do most of their work during the morning shift (typically 7.00 a.m. to 2.00 p.m.) and in the afternoon and night shifts provide only additional services to business districts and finish work that was not completed during the morning shift.

Some workshop managers are reluctant to deploy their vehicles on more than one shift each day, arguing that the vehicles need to be rested or maintained during the other shifts. However, in many situations it may be more economical to use expensive vehicles more intensively and maintain adequate levels of availability[17] by spending more on maintenance, having one or more extra backup vehicles and expecting a shorter economic life from vehicles that are regularly used for two shifts. It is wise to base decisions on such matters on operational data and calculations, in cases where managers have the opportunity to consider alternatives.

4.2.4 Days of the week

"Daily collection" may mean six days a week (with no working on the weekend rest day) or seven days a week. Providing a collection service seven days a week requires a larger workforce so that employees can have one day off each week and may cause problems for supervision (unless extra supervisors and managers are appointed or they agree to work or be on call seven days a week). Even if collection services are provided seven days a week, it may be necessary to provide storage capacity sufficient for the waste of two days if services are suspended on national holidays or religious festivals.

Collection "on alternate days" generally means three days between collections over the weekend, and a greater load of waste to collect after the weekend. In the same way, collection twice a week means collection once after three days and once after four days.

4.3 POINT OF COLLECTION

The point of collection is the location at which the waste passes from the control of the generator to the control of the collection agency. It is the interface between the service recipient and the service provider. The generator is responsible for the task of taking the waste to the point of collection, and so is concerned about the time and effort required and must be willing to do this work. The collection agency is concerned about the costs of the collection operation, difficulties in access and loading the waste, and problems that occur when the generators fail to do their part. The cost of collection from community storage is less than collection from each dwelling, provided that significant quantities of waste are not scattered on the streets and containers do not need to be replaced frequently. Waste pickers may be concerned about whether they can have access to the waste, both in terms of its location and the time during which they will be able to work with it. There is also a general concern about general environmental aspects, including:

- whether the waste will be scattered by wind, animals, children or waste pickers before it is collected,

17. *Availability is the proportion of time that a vehicle is ready for service (that is not awaiting servicing or repairs).*

- about the smell or pollution caused by the waste while it is awaiting collection, and, in this connection, the proximity to houses or businesses,
- regarding the appearance of the waste and any obstruction it may cause to traffic or pedestrians, and,
- whether insects and rats will be able to breed in or near the storage facilities.

Some of these impacts are also affected by the design of the containers, which will be discussed in the next chapter. Social factors, particularly regarding access by strangers into private property, must also be considered.

There are three locations where the waste can be transferred to the collection agency

- in the street at a short distance from the generator's property
- in the street at the property boundary, and
- inside the property.

4.3.1 In the street

a) Community Containers – These containers are sometimes known as communal containers or street containers. In this system, householders bring their wastes to predetermined locations where there is usually some form of community storage facility, and refuse collection vehicles visit these sites at frequent intervals, usually once daily or every second day, to remove accumulated waste. The principal advantage of this method of collection is that it reduces considerably the number of sources from which waste has to be collected. The economy that results from the reduced number of collection points could be a false one if the containers are too widely spaced and there is poor public co-operation resulting in wastes being thrown on the ground to avoid having to bring them to the container. If this happens the task of collection will be transferred to the street sweeping service which is more expensive than collecting from containers.

The spacing at which community storage facilities should be located depends on the extent to which a community is willing to co-operate in their proper use by carrying their waste to the containers rather than dropping it in the street or on open plots nearer to their homes or businesses. Typically the containers should be spaced so that the distance between any two containers does not exceed 200 metres (some studies in South America showed that 160 metres is the maximum distance over which the residents, often children, are willing to bring their wastes). In congested areas especially it may not be possible to locate containers at convenient distances. In traditional or informal housing areas where community containers can only be located on the main streets – in places where there is enough space for the container itself and adequate access and space for the collection vehicle – the distance from some remote houses to the nearest container on a main street may be considerable, but the residents may be accustomed to taking their waste on their way to school or when they go to collect water. The local residents must be involved in decisions affecting the location of storage points.

This system provides a relatively low level of service at a low cost. It is appreciated by residents who do not wish to store their wastes in their dwellings because they can take their wastes out to the street container at any time. The collection agency is able to collect the waste at any time of the day or night to suit its convenience.

Street or community containers are regarded as unacceptable in some cities because waste is always present and visible on the streets, giving the streets an untidy appearance. Residents and shopkeepers may object to having a container close to their premises because of the perceived health threat, the smell, the presence of dogs, cats and birds, or other aesthetic reasons. But they also want the container to be close enough so that children can take the waste to the bin without crossing a busy street or walking a long way.

Burning of wastes in containers can be a serious problem where community containers are left unserviced for any length of time. The wastes attract flies and start to decompose, causing odour problems. In such situations there is a tendency for nearby householders to set the waste on fire to prevent these problems, but this can cause an even more serious problem as the burning of wastes at a low temperature, particularly if the waste contains plastic materials, releases gases containing dioxins and furans which are serious health hazards. It is difficult to stress sufficiently how serious a long-term hazard this can be. Legislation to prevent burning should be introduced and enforced rigorously in all countries. Furthermore, burning damages metal containers by removing the protective coating that prevents corrosion and plastic containers melt and are totally destroyed. It is therefore essential that any community container is emptied regularly – every two days or, at the very most, every three days – before the waste starts to decompose and causes householders to complain. In colder countries a weekly collection may be acceptable.

Chapter 5 discusses the types and designs of storage facilities that are appropriate for this collection system.

b) Block collection system – This method of collection is used in many countries. In this system, a collection vehicle travels a predetermined route at prescribed intervals, usually every two to three days, and stops at selected locations where a bell is sounded. Alternatively the vehicle may play music as it drives along to notify householders of its arrival. Upon hearing the signal the householders bring their refuse to the trucks and hand it over to the crew who empty the containers and pass them back to the householders. Sometimes the residents load the waste into the vehicle themselves. No containers are left in public places. Vehicle and labour productivity of this system lies between low and medium. The timing must be such that there are residents or servants in the properties to bring out their waste, otherwise the waste will be left out in the street.

4.3.2 At the property boundary – kerbside collection

Under this arrangement, the collection crew collects waste in bins, bags and other containers which have been left at the roadside. In some places the waste is just left in a pile, requiring considerably more effort from the collection service. The residents and shopkeepers must be informed beforehand about the days on which collection will take place so that they can put out their waste in time for collection. This system requires a very regular and well-organized collection service so the householders know when to put out their wastes. Delays in the collection service result in waste being left out for more time, increasing the chances that it will be scattered. Where collection is irregular, it is common to see the containers placed permanently outside, with increased incidence of the scattering of wastes by waste pickers and animals, and increased risks that containers will be stolen or damaged.

There are problems also when the residents fail to do their part. It is not uncommon for residents to complain that the collection service has neglected to do its work when the fault actually lies with the residents themselves for not putting their waste out for collection at the correct time.

Kerbside collection can also be used in conjunction with ringing a bell or other signals to invite householders to set out their waste containers. The increased use of this option could reduce some of the disadvantages of the system relating to the scattering of refuse by scavenging animals, theft of containers and traffic accidents caused by rolling bins. Certain refuse vehicles, such as handcarts with steel wheels and compactor vehicles, effectively signal their arrival through the noise they make during normal operation, and, where such vehicles have been used, improved efficiency in setting out and retrieving containers has been noted. Households that have no-one at home when the collectors come can still put their containers out before they leave home.

Kerbside collection is perhaps the most commonly used method in high-income areas of the industrialised countries, having replaced back door collection as labour costs became excessive. The vehicle and labour productivity of this method of collection can be enhanced by using standardized containers and providing a less frequent collection service. Unfortunately climatic conditions generally dictate that waste in developing countries should not be stored for periods in excess of four days, so if household generation rates are low this method of collection is rarely economical in low- and medium-income areas.

In some industrialised countries residents are required to segregate their wastes into two or more categories and put these different wastes out for collection at different times and/or in different containers. This approach is seldom practical in developing countries where the segregated items from high-income areas may be collected by the private or informal sectors on a commercial basis but where the higher costs of separate collection cannot be justified in lower- income areas where there are smaller amounts of recyclable materials in the wastes.

4.3.3 Inside the property

a) Back door collection – This system requires residents to do no more than to store their waste in their yards outside their back doors. The collection crew enters each property, takes out the container, empties the waste into the collection vehicle and returns the container to its place outside the back door, not forgetting to replace the lid. The lack of householder involvement in the collection process results in increased labour costs for entering all premises and frequent delays while waiting for gates to be opened. Where labour costs are high, this method[18] may be twice as expensive as kerbside collection. This method is becoming less common in industrialised countries and is rarely practised in developing countries. In some communities, the intrusion on privacy and security prevents the consideration of this method as a possible option. Furthermore, the back door collection method may be affordable only if collection is infrequent, typically

18. *Reference [Betts 1978]*

once per week. The more frequent collection intervals necessary in hot climates result in poor vehicle productivity and, hence, very high costs.

b) Collection from apartment buildings – There are two further options for multi-storey apartment buildings. One is to provide storage outside or at the ground floor, from which the waste can be collected by the collection service. Wastes may be brought to these containers by the residents themselves, by the caretaker of the building or by means of vertical refuse chutes that have openings on each floor so that residents can put their waste into the chutes so that it drops into containers at ground floor level. (Such chutes have proved very problematic in many situations, becoming blocked and odorous, or encouraging the breeding of cockroaches. They must have smooth interiors, be always used in a disciplined way and be cleaned regularly.)

Another alternative is that the cleaning service workers collect waste from each individual apartment, either picking up the waste that is left outside each door or knocking on the doors to ask the residents to hand over their waste. This is clearly very labour-intensive, but has proved to be sustainable in middle-class areas of Cairo.

4.3.4 Special collections

Bulky waste and garden waste (Section 3.1) can be collected in a number of ways. Since the generation of such waste is often at irregular intervals, the collection agency may provide a service which collects bulky waste on request. Households and businesses are informed of a telephone number which they can dial, or an office they can visit, to request that particular items or materials are collected from their premises. The unwanted items must be clearly described or identified with labels so that no valued items are removed at the same time, by mistake. Collection may be from outside or inside the property. A fee may be charged for this service, but, in order to avoid this fee, people may dump their bulky waste on open ground, from where it may be more costly to collect it. The agency responsible for maintaining public parks and roadside trees should co-ordinate closely with the waste collection agency to ensure that waste foliage is removed as soon as possible after it is generated. Large open trucks, preferably with a hydraulic crane fitted with a suitable grab attachment, should be used for such collections. A shredder on a trailer that is towed by the truck would be very effective in reducing the volume occupied by tree branches so that fewer trips are necessary. Alternatively, a crew should be dispatched to cut up any tree branches (in order to reduce their gross volume) and prepare them for loading before a truck comes to collect the waste.

If bulky waste and green waste from gardens are generated at reasonably predictable quantities or intervals, the collection agency may distribute some large skip containers in the streets at times that are announced so that residents can carry their waste to the skips and deposit it inside them. The containers should be removed and emptied before the wastes in them have time to decompose and cause serious corrosion of the containers – within two days if the wastes have a high moisture content. In industrialised countries where the levels of car ownership and environmental awareness are relatively high, residents may be willing to take their bulky waste to a transfer station or disposal site. A fee may be charged for the handling and disposal of this waste.

During the Muslim festival of Eid ul-Azha, many families sacrifice sheep or other animals at their homes, and this can generate large quantities of bones and offal which should be collected within 24 hours.

Whenever the presence in a street or public area of the carcase of a large animal is reported, it should be removed quickly as a matter of top priority.

4.3.5 Conclusions

Often the most productive and economical approach for any city is a combination of these methods – different methods being used in different parts of the city. The system and frequency that are chosen should be dictated by the willingness to pay of the householders.

The many different types of storage containers are discussed in Chapter 5. In selecting and designing a container it is important to think not only of the container itself, but also of how convenient it is for the public to use and how it can be emptied and the contents loaded into the different types of collection vehicle that may be used. Chapter 7.presents criteria for selecting the best combination of equipment and collection methods, so that coverage is maximized and overall costs are minimised.

Table 4.1 summarises the options for point of collection.

4.4 METHODS OF LOADING AND TRANSPORTING WASTE

4.4.1 Loading

The method used to load waste from the storage container into the collection vehicle must be given careful consideration because of the impacts on the cost of the service and the health of the labourers. In situations where labour

Table body and header changed in this table

Table 4.1 Comparison of various methods of solid waste collection

Description	Community containers	Block collection	Kerbside collection	From inside the property
Householder co-operation in carrying refuse bins or bags	Yes	Yes	Yes	No
Householder co-operation in emptying refuse bins	Yes	Optional	No	No
Need for scheduled service	No	Optional	Yes	No
Waste pickers' access to waste	Very high	None	High	None
Average crew size (excluding driver)	1–2 (portable) 2–4 (stationary)	1–2	1–4	2–6
Complaints regarding trespassing	No	No	No	Yes
Level of service	Low	Fair	Good	Good
Collection cost per household	Low	Medium	High	Very high

costs are low it is common to see very slow methods of loading waste, but it must be remembered that this keeps the vehicle waiting for long periods and reduces the number of trips it can do in one day, and so can have a significant impact on the cost of collecting each ton of waste, even if it is considered that labour costs are not important. Health and safety risks must also be kept in mind, because some loading methods expose labourers to risks from inhaling dust and fungal spores, from skin contact with the wastes (either to their hands or to their feet and legs), from lifting injuries and from traffic accidents. In many situations manual loading methods cannot be avoided, but a good manager is aware of the risks and does whatever is possible to reduce them.

Examples are given elsewhere in the report that emphasise the importance of mechanical compatibility between containers and vehicles. It is important to consider the adequacy of standby arrangements in cases where a container can be emptied by only one type of vehicle, and flexibility so that it is possible to use two or more different types of vehicle to collect from a particular type of container.

In selecting a container and collection system, it is important to consider the space needed by the container, and if the container is to be lifted or emptied mechanically there must be a way of ensuring that parked cars and other obstructions do not prevent the collection vehicle from getting close enough to the container.

4.4.2 Separate or combined collection

It is surprising how many accounts there are of initiatives to encourage household segregation of wastes (so that recyclables are kept separate from other wastes) where little thought has been given to the separate collection of the two or more streams. There are various kinds of vehicle that have been designed to collect different types of waste in separate compartments, but such systems are very expensive and not suited to the economic and social conditions in developing countries. In such situations it is better to encourage the informal or private sectors to collect the recyclable fraction, as already mentioned in Section 4.3.2

It may, however, in some circumstances, be appropriate to consider collecting some types of waste separately. For example, wastes from markets, restaurants and hotels may be collected separately from wastes from other sources if they are to be used for animal feed or composting (because they are likely to be less contaminated by harmful materials). For the same reason, street sweepings may be collected separately from domestic wastes. Furthermore it may be decided not to mix waste from certain industries and hospitals with general municipal wastes if the former are to be deposited in a separate part of a landfill where waste pickers are not allowed to operate. High-density wastes such as industrial sludge, construction and demolition waste and street sweepings containing large amounts of sand may be collected separately from low-density wastes because the two types require different types of container or vehicle. Such measures are more concerned with the location of containers and the routing of vehicles than with segregation and sorting.

4.4.3 Direct collection or transfer

In many cases the vehicle that picks up waste from the point of collection (Section 4.3) can take the waste directly to the final destination (treatment plant or disposal site), as shown in Figure 4.1.a. However, if the vehicle that initially collects the waste is small and/or the time that it would take to get to the final destination would be long, it may be economical to transfer the waste (together with waste from other similar primary collection vehicles) to a larger and/or faster vehicle (Figure 4.1.b). If waste is collected from high-density housing areas with narrow streets, a two-stage system is almost always required. The waste may be transferred from the primary vehicle to the secondary vehicle at a special transfer station or at one of a number of transfer points. In some cases there may be benefits in having three stages of collection. Adding stages and transfer operations increases the complexity of the system, requiring more management effort and risking lower reliability.

Transfer may allow some tasks to be performed during the day, and others at night or when there is less congestion.

Sometimes the organisations responsible for primary and secondary collection are different. One example is when a municipal organisation collects waste from houses and shops, and a regional organisation operates secondary transport and disposal. Another example is when waste is collected from houses by a community-based scheme and it left at a transfer point for removal by municipal vehicles. This second case is often problematic, because the removal by the municipal service has proved to be unreliable in some cases, drawing criticism to the community-based scheme. Such difficulties have been overcome by personal contacts with municipal officials or by making unofficial payments to municipal truck drivers.

As a general rule the choice of the optimum collection system is greatly influenced by the distance between the collection areas and the disposal site.

Figure 4.1 illustrates direct collection and transfer. Transfer is discussed in more detail in Chapter 8.

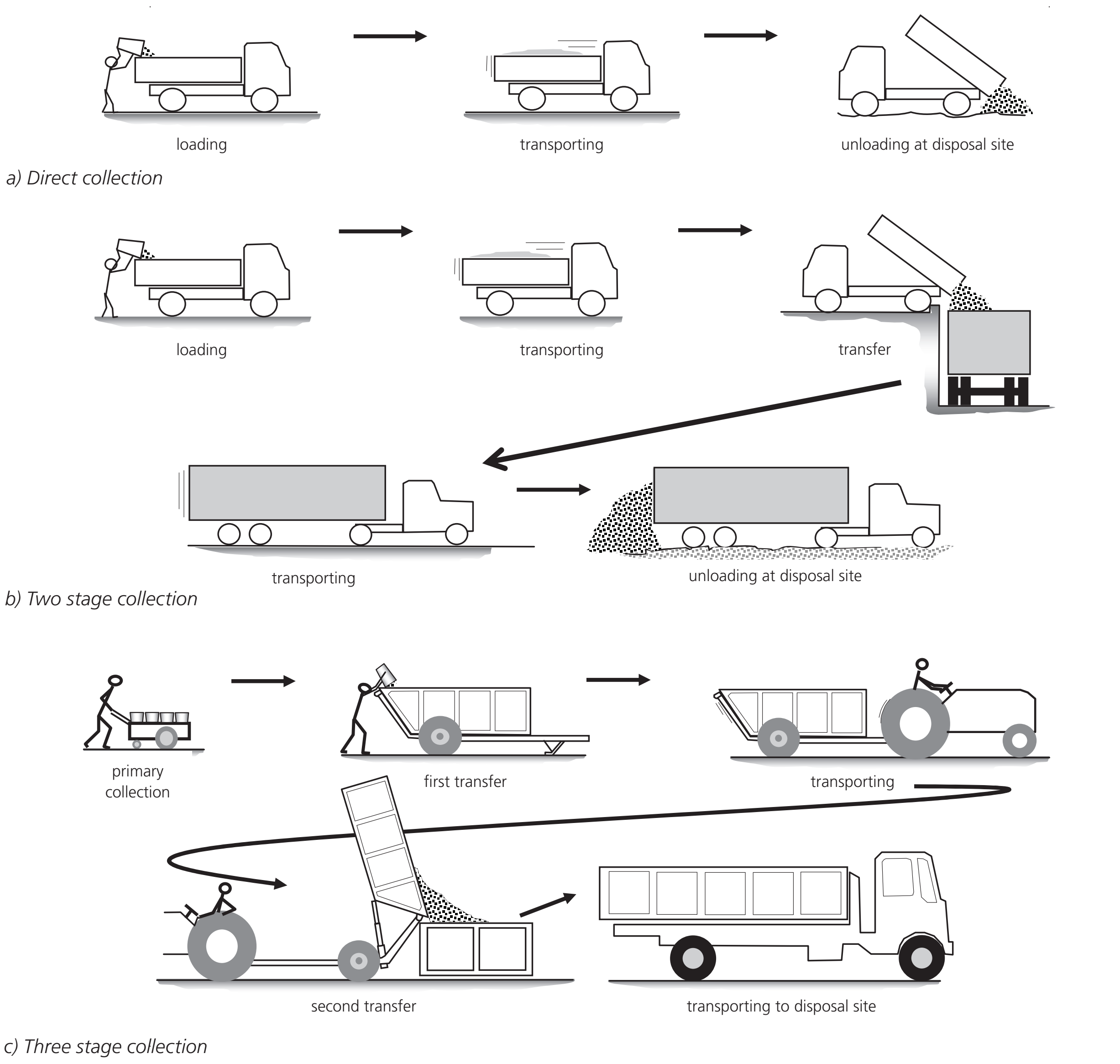


Figure 4.1 Examples of collection systems

4.5 STANDARDISATION

Most cities can be subdivided into zones with different characteristics. Many cities have old, traditional core areas which were developed before motor vehicles were commonly used, and the access to housing in these areas is via small lanes which are too narrow for four-wheeled motor vehicles. Unplanned informal squatter or slum areas are often built without providing access for motor vehicles. Some more modern residential areas were built on narrow roads which are often obstructed by parked cars so that they are accessible only to small vehicles, and travel times are slow. Some residential areas have a high population density, where houses are small or there are high-rise apartment blocks. Other districts, especially in peripheral areas or in areas preferred by wealthy residents, have relatively long distances between each house.

In addition to these differences in road access and housing density, there are also differences in the type of service that is required. Wealthy residents have more space for storing waste and may have servants to manage their waste, and they may wish for a higher level of service and be willing to pay for it. In high-density areas it may be necessary to collect the waste more frequently because of the lack of storage space, both in the dwelling and in the street.

Because of these differences it is not possible in many cities to have one system of waste collection. The various systems and vehicle types must be selected for each type of area so that each area has a system that is economical, reliable and acceptable to the residents.

With this in mind, it is important to keep the number of different systems and vehicle types to the minimum, for the sake of maintenance. Each type of vehicle requires a specific set of spare parts and mechanics should be familiar with each type, and able to monitor its condition and maintain it. As will be discussed later, it is important to select vehicle makes and models that are commonly used for other purposes in the country concerned because this increases the opportunities for buying spare parts directly from local agents, thereby avoiding the delays associated with buying parts from overseas.

There are some occasions when a city has funds to buy many vehicles at one time. It is important to consider very carefully which type and manufacture of vehicle to buy because a bad selection can be a very expensive mistake. If it is not possible to buy one vehicle first and test it thoroughly, workshop engineers and mechanics should investigate the performance and reliability of the proposed type of vehicle in other locations where they are already operational. It is not advisable to rely on the information provided by the manufacturer, and it is better to see oneself rather than rely on what others say. If a loan or grant is obtained for purchasing vehicles and storage equipment, the procurement procedures of the financing agency may dictate that price is the only criterion. In this case it is very important to write the specification in such a way that unsuitable systems are excluded. Whenever possible, tenders should include the following clause

> *"The lowest tender will not necessarily be accepted. Only makes which have a proven performance over a number of years in local municipality applications in the country / region will be considered. The tenderer will be asked to provide evidence of local service facilities and adequate spare parts stocks in the country / region."*

If vehicles are supplied in smaller numbers by various donors, it may be very difficult to implement a standardisation policy since different donors are likely to provide equipment from their own countries and to their own specification. If vehicles are provided through the national government it may also be difficult to ensure standardisation and the provision of the most efficient types of vehicles.

Summary points

- In selecting a system for storage and collection there are many options and aspects that should be considered.
- The residents who will benefit from the system should be consulted regarding the desired level of service and the type and location of storage units.
- Systems that use community containers are usually cheaper, but are sometimes unpopular.
- In some situations it is necessary to transfer waste from a primary collection vehicle to a secondary transport vehicle.
- Standardisation of vehicles aids maintenance but many big cities with diverse areas need more than one kind of collection system if they are to provide a service to all citizens.
- The availability of spare parts and servicing is a crucial factor in choosing vehicles.

5 STORAGE SYSTEMS

5.1 INTRODUCTION

Storage, loading, transport and disposal are the four essential elements of any solid waste management system. Compatibility between each of the three stages of storage, loading and transport is essential to ensure economic operation – they should all fit together and be designed with the others in mind. The objective should be to develop a fully or partly containerised storage, loading and transport system, which does not allow the waste material to come in contact with the ground at any stage of the collection system. Keeping the waste in containers is hygienic, and minimises handling and loading times, but under some economic conditions it appears that less satisfactory collection systems, that deposit waste on the ground and then load it, cost less per ton. Containers can be a very significant part of the costs of a collection system (Annex A3), particularly if the containers quickly become corroded or damaged or need to be replaced frequently for other reasons.

Solid waste storage facilities for domestic wastes may be classified as household (that is, household bins or bags, sometimes known as *primary* storage) and community (that is, containers or bunkers, each used by many households, known as *secondary* storage). The storage volume required for domestic wastes is a function of the number of people served, the daily rate of waste generation per capita, and the number of days between successive collections. Storage capacities required for commercial and institutional premises are determined according to the size and nature of the activities as well as the number of people involved.

A waste bin or other storage facility must satisfy many requirements:

a) **Convenience** – It should be convenient to use – not too high for children to use, and with a large enough opening so that all acceptable objects can be placed inside it. If the container is used by more than one household, there is a risk that waste will be dumped near it rather than in it if it is not convenient to use, and when there is waste around the container, this will discourage others from putting their waste inside, since they will not want to walk on the surrounding waste.

b) **Size** – It should be large enough to accommodate the wastes that need to be stored in it, taking into account the longest expected interval between visits of the collection team and fluctuations in waste generation. Bulky items such as cardboard boxes and foliage can quickly fill a container, but it is generally not reasonable to design for such items. (There is more on this subject in Section 5.3.2.)

c) **Loading** – The loading of the waste into the collection vehicle should be economical (considering both the labour required and the time that the collection vehicle is waiting), hygienic (so that the collection labourers and any others in the vicinity are exposed to the smallest possible risk) and safe (not presenting a serious risk of injury from lifting or cuts). If loading can only be done using a particular type of vehicle, standby arrangements and vehicle maintenance should be sufficient to ensure that this type of vehicle is always available.

d) **Shape** – Containers should be tapered (that is having bigger plan dimensions at the top than at the bottom) so that they are easy to empty when tipped, even if the waste has been compacted into them. Damaged containers may trap waste inside them if the damage makes them smaller in one dimension where the damage has occurred, in comparison with the base.

e) **Isolating the wastes** – It is desirable that there is no access to the waste for flies, animals and rain, but these objectives may be difficult to achieve in practice, especially if the container is used by many people. A well-fitting lid can be effective for these purposes, provided that the lid is kept closed most of the time. However, often users fear getting their hands dirty and are unwilling to open the lid, and so they dump their waste nearby. If the lid is already open, users may be unwilling to close it, in which case flies have access to the waste for laying their eggs, animals and birds scatter the waste, and entering rainfall adds to the weight that is to be collected and accelerates decomposition. Lids often become damaged or lost. Sometimes the lids are too high for children to reach. A possible alternative is a fixed sloping cover with a side opening; this can be effective in preventing rain from reaching the waste but makes it more difficult for the users to empty their containers. Some containers that are tipped to empty and have a large lid to permit this emptying also have small openings or hatches with lids for the use of people who are tipping their waste into the container.

There should be no contact between the waste and soil, because fly maggots burrow into soil to complete their development (Box 2.1). Furthermore, if there is no firm base to the storage facility it is likely that wastes mixed with soil will be left behind by the collection crews, or that the ground will gradually be excavated as soil is removed with the waste. If concrete pads are designed for the containers to rest on, they should be designed to prevent rats burrowing underneath them, by extending the sides down into the ground or using mesh

f) **Durability** – The containers should be sufficiently durable, resistant to mechanical damage, corrosion, ultra-violet radiation and, in many cases, hot ashes or fire. Containers that have a relatively short lifetime may be economical if their costs are low and there is a reliable mechanism for replacing them. Bins that are designed for use in industrialised countries where waste densities are low will be seriously overloaded if filled with wastes that are four or more times denser. In particular the wheels of such containers become damaged very quickly by these unforeseen loads, especially if the containers are pushed over rough or soft ground.

Containers made of ordinary mild steel corrode quickly if organic wastes are left in them for periods that are long enough to allow the wastes to decompose to form acidic liquids. Corrosion occurs more quickly in containers that have sharp corners and crevices where wastes adhere or liquids become trapped between the steel sheets. Careful design of the containers to eliminate corners and crevices greatly increases the life of the containers. Another means of increasing the life of containers by slowing corrosion is to manufacture them from special corrosion-resisting steels, which are more costly than mild steel (Box 5.1). If mild steel containers are set on fire they should be cleaned and repainted immediately as the heat will destroy any protective coatings, including galvanising and paint, or grease from the food wastes, and rusting will start immediately.

Some other points that are specific to only one type of storage facility are mentioned in the following sections.

Box 5.1 Additional information

Using CorTen steel to increase container life

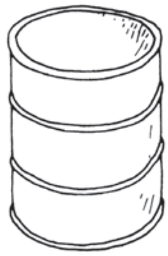
CorTen steel, which contains a small proportion of copper, represents a compromise between using expensive materials that are almost completely resistant to corrosion, and using mild steel which corrodes relatively quickly when used for solid waste containers. CorTen steel is not as resistant to corrosion as stainless steel (which contains nickel and chromium) or semi-stainless steel (CR12) which contains 12% chromium, but it has approximately seven times the corrosion resistance of ordinary "mild" steel and will increase life expectancy by up to five times while it adds perhaps 30% to the cost of each container. The copper in the steel forms a protective copper oxide as the steel ages. It also contains additional carbon to increase its strength so that thinner steel sections can be used.

5.2 HOUSEHOLD WASTE STORAGE

A variety of facilities are used for household storage of solid wastes. Temporary containers, such as cardboard boxes, plastic bags and a range of different types of containers are often used. Plastic bags are suitable in a number of ways – they contain moisture if they have not been torn and they are relatively clean and easy to handle. It is also preferable that plastic bags are filled with waste rather than discarded empty and therefore easily carried by the wind. One disadvantage is that they are easily torn open by dogs and cats, and another is that sharp objects can easily pierce them to cause injury to the person who is carrying them. Cardboard boxes lose their strength when they become wet because of the waste they contain, or when coming into contact with rain or moisture from the ground. Some improvised metal containers have jagged edges which can cut hands that lift them.

The introduction of a reliable collection service often leads to the use of larger and more durable containers such as those shown in Figure 5.1 The provision of permanent containers may be the responsibility of the collection agency or the householder, or it may be encouraged by a public education campaign. The supply and distribution of large one-trip plastic refuse bags adds significantly to costs and is seldom appropriate because they are used for other purposes and are easily torn by scavenging animals. Sometimes plastic bags are used as a means of paying for the waste collection service (Box 5.2). Reusable heavy-duty plastic bags proved to have an average useful life of six months in Zimbabwe in the 1980s. Many common types of household waste storage are not kept covered or enclosed and so do not discourage the breeding of flies. Plastic and galvanized steel bins with lids are commonly used in middle-income and high-income areas, but they are relatively expensive and so they may be stolen. Containers made from used car and truck tyres, with capacities ranging from 30 to 80 litres, when fitted with a suitable lid, offer a useful, fly-proof, washable, robust and low-cost storage solution (see Figure 5.1 and Photos 5.1).

Two hundred litre oil drums are used as storage bins by households and commercial and institutional premises. They are, however, very heavy to handle and do not facilitate speedy loading into collection vehicles. It is not uncommon to see them being tipped over to empty their contents onto the road, so that the waste can be loaded into the collection truck using a shovel or by raking it into small buckets, baskets or bowls. This is a slow, laborious and unhygienic system that results in poor vehicle utilization and low labour productivity. The fact that drums are rarely covered also makes them very unattractive for widespread application. An improvement is to cut the drums into two and weld handles to them. A further disadvantage may lie in the fact that the drums are cylinders, their sides parallel. When the waste is compacted into them, it may be difficult to tip the waste out, especially if the drums are a little deformed or damaged. (As already mentioned, containers for solid waste should be tapered, wider at the top than at the bottom, so that the waste falls out easily when they are tipped.)


200 litre oil drum


100 litre half oil drum


galvanised bin

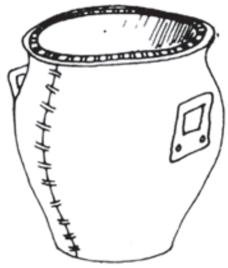

bin made from tyres

Figure 5.1 Many different types of bin are used for storing waste at the household


a) Halved oil drum


b) Durable bin made from old truck tyre


c) Plastic bags are subject to scavenging by animals


d) Recycled steel drum


e) Thin gauge galvanised bins are easily damaged


f) Plastic bin with liner

Photos 5.1 Some examples from the wide range of options for primary storage

Box 5.2

Collection using pre-paid bags

One method of obliging generators to pay for a waste collection service is to inform them that waste will be collected only if it is presented for collection in official plastic bags or if it has a special ticket attached to it. The bags are sold for a much higher price than the cost of an ordinary bag, because most of the income from their sale is used to pay for the collection service. This system can be used where there is a demand for a waste collection service, for which households are ready to pay, or if there is an effective enforcement system. It may also be used where there are several private operators in competition with each other (in which case each operator uses a distinctive colour and prints its own logo on its bags). The bags may be sold by local shops or by company employees going house-to-house. The private operators travel through all the streets and pick up their own easily identifiable bags. There can however be a problem if waste pickers collect the bags at the disposal site and then wash and resell them, or they may even tip out the bags in the street so they can resell them, in which case the waste is not even collected. Some types of compactor trucks have ripper teeth in the compaction mechanism to ensure that all the bags are torn, both to reduce the air in the bags (to increase the compaction) and to discourage scavenging, but this is only practical with compaction vehicles which are seldom cost-effective in developing countries but may be suitable in some higher income areas.

The plastic *tote bin* or *wheelie bin* (Figure 5.3) represents a useful mobile alternative but is susceptible to theft and requires special mechanical bin lifting equipment fitted to the refuse collection vehicle for efficient loading. It is also not suitable in locations where wood, charcoal or other solid fuel is used for cooking or heating as it is easily damaged by hot ashes.

For high density wastes, the need to take account of a man's capacity for repeated lifting might limit the volume of primary storage bins to between 50 and 60 litres.

Depending on the method of waste collection, the standardisation[19] of household storage bins could maximise labour and transport productivity. This is especially true for waste collection methods that rely on the direct loading of household bins by collection labourers. No such advantage is derived from standardising household containers if the service collects from community storage. Standardisation of primary bins does, however, pose a considerable problem with regard to their distribution and replacement. Provision of these bins would add considerably to capital costs, and in many cases householders would not be able to afford to buy them. Standardisation of primary storage might, therefore, only be suitable when waste generation rates are high, and only in high-income or commercial areas of developing countries.

5.3 COMMUNITY WASTE STORAGE

5.3.1 Introductory comments

The use of community containers, filled either directly by residents or from primary collection vehicles (such as tricycles or handcarts) is particularly appropriate in densely populated residential areas, such as low-income to medium-income areas with single family dwellings, or multi-storey housing in all income groups. Community waste storage facilities may be either stationary (fixed) or portable, and portable containers may be emptied in-situ or replaced with empty containers.

5.3.2 Required capacity for community storage

The capacity or volume required for a community container depends on the following factors:

- The volumetric generation rate for the households and commercial premises that are expected to use the container, which is usually estimated by dividing the generation rate on a weight basis by the density of waste at the community storage stage (Section 3.2.2). Much depends on how and where the density is measured. The self-weight of the waste will compress the lower layers, especially if the waste includes cardboard boxes that have not been flattened, plastic bags containing air and bulky organic matter (such as banana leaves) which can be compressed. It is better to measure the density of the waste as it is found in the container just before collection than to try to estimate the density based on measurements made at the household.
- The number of people expected to use the container. It may be difficult to know how many people will use any particular container. Residents may not use the container nearest to their dwellings if it is not in the direction that they usually go (to school, work or shops, for example) or if it must be accessed by crossing a busy road. Numbers using the storage will increase if new housing is built in the area.
- The type of container. A taller container may provide more compaction of the lower layers of waste caused by the waste above, but tall containers may be difficult for children to use, so that more waste is dumped outside the container. Covered containers that are filled

19. *Standardisation of containers and bins means that only one size and design of container is used. Standard bins would be provided by the waste collection agency, either at its own cost or by billing the householders. Waste in any other type of container would not be collected.*

through relatively small openings in the cover may not be filled completely because the waste may form a mound inside the container to block the opening while there is still empty space beside this mound inside the container.

- Other types of waste that are expected to be put in the container, such as street sweepings, garden waste, construction and demolition waste and commercial waste. If street sweepings are added, this will be on a regular basis and so should be allowed for, but amounts may vary with days of the week and after events such as football matches. On the other hand, garden waste is usually generated in large quantities at only certain times of the year, and so it may not be reasonable to allow for this when estimating the capacity needed for community containers. Small quantities of construction and demolition debris resulting from minor construction and renovation of dwellings may also be put into community containers. Although the containers may be intended only for household waste, shops and offices in the area may use these containers because they are more convenient or to avoid making payments for commercial waste collections.
- The longest expected interval between emptyings. If the waste is collected six days a week there is an interval of two days over the rest day. (For example, if Sunday is the rest day and the waste is collected early in the morning from Monday to Saturday, the waste of Saturday and Sunday must be collected early on Monday morning.) In the same way if collection is three times a week the longest interval between collections is three days, the other intervals being two days each.
- Seasonal, weekly and random variations in the quantities of household waste should be allowed for. Random variations tend to become less significant when more households are involved as quantities get “averaged out”.
- If the container will be supervised by a municipal employee, it may be possible to allow a lower storage capacity because the employee can distribute and compact the waste in community containers to make space for additional loads. It is very unlikely that residents using a community container will try to rearrange or compact the waste if the container is full; instead they will simply dump their waste on the ground nearby.

If a stationary container (such as a masonry bunker) is to be provided, it may be possible to allow additional capacity at very little extra cost, in order to allow for uncertainties. However concrete bunkers cannot generally be recommended (see caption of Figure 5.2). If portable containers are used, they should be distributed according to anticipated waste volumes and monitored closely so that containers that are overfilled can be supplemented by additional containers.

Table 5.1 suggests the capacity required for community storage for a neighbourhood that generates an average of one cubic metre of waste each day, for different collection frequencies. It can be seen that, for daily collection, collecting seven days a week almost halves the storage requirement, compared to working six days a week.

Because of all the uncertainties regarding storage requirement that are outlined above, it is important to incorporate either extra capacity or flexibility into the storage arrangements – extra capacity for storage facilities that can be enlarged at minimal cost and flexibility in the case of portable containers that can be moved or supplemented as required.

5.3.3 Stationary (fixed) facilities

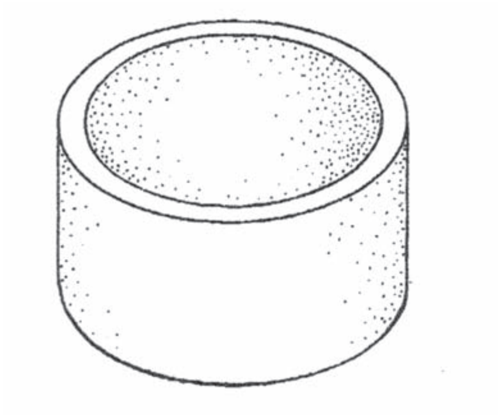
The most common stationary units are

- uncovered masonry bunkers[20] with capacities between 1 m^3 and 5 m^3 (Figure 5.2 and Photo 5.2.b)
- covered galvanized or masonry bins with capacities up to 2 m^3 and access for loading at the top and unloading through a side flap door; and
- concrete or steel pipe sections with capacities up to 300 litres (Photo 5.2.a).

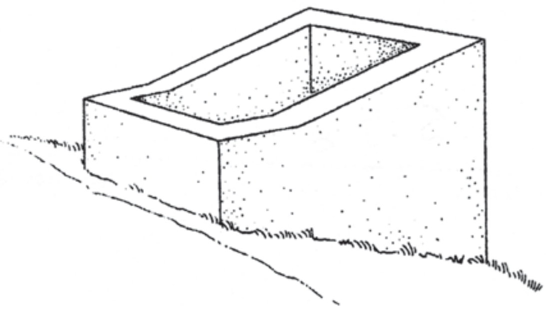
20. *Bunkers are also known as compounds and enclosures.*

Table 5.1 Capacity required for community storage for average generation rate of 1.0 m³/day

Collection frequency	Daily, 7 days/ week	Daily, 6 days/ week	3 times/ week	2 times/ week	Once/ week
Longest interval before collection (days)	1	2	3	4	7
Required capacity if unattended (m³)	1.5	2.5	3.5	4.8	8
Required capacity if supervised (m³)	1.3	2.3	3.3	4.5	7.5



Concrete pipe can be turned over for easier and faster emptying



Concrete bunker must be emptied by hand. Only one person at a time can work within the compound

Figure 5.2 Fixed community collection points can cause problems with flies, rodents and smells. They are slow to empty, resulting in poor vehicle utilisation

a) preparing to empty a concrete pipe container

b) Community bunker (compound); difficult to empty

Photos 5.2 Fixed community containers

All three types of secondary storage facilities have been tried frequently and have failed consistently. Waste is often scattered around the facility, and insects, rodents and animals are attracted to it (Photos 5.2). Except for covered bins, no protection is provided against the ingress of rain. Besides creating aesthetic and health problems, stationary waste storage facilities are operationally grossly inadequate. Waste has to be removed by raking it out onto the ground and loading it into baskets before it is carried to the vehicle. (An alternative method, which can be used with rear-loading compactor trucks because of their low loading height, is to rake the waste out onto sheets which are used to throw the waste into the truck's hopper.) This is often a demeaning, unhealthy and time-consuming task, which limits the productivity of both labour and vehicles. The continued usage of stationary secondary waste storage facilities cannot be justified. Unfortunately, municipal authorities which have no choice concerning the type of vehicle that they are given and are not free to manage most of their expenditures may have little choice in the current situation but to continue with this method.

Hinged or sliding lids are often provided but they are rarely used as intended, sometimes because the lids are too high or too heavy for children to operate, or because they are considered to be dirty and so no user wishes to touch them. Closed lids encourage the dumping of waste nearby rather than in the container. The openings of the storage units should be in the top surface to allow emptying of buckets and bins into the container. It may be wise to locate community storage containers inside simple shelters in areas of intense rainfall.

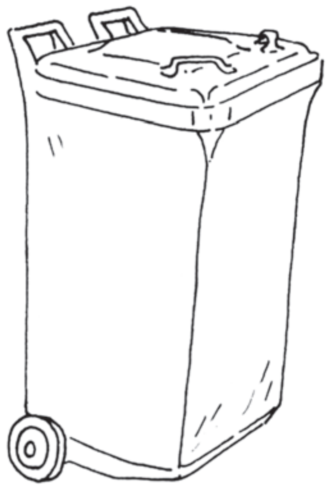
5.3.4 Portable bins emptied in-situ

A better solution, which is much more efficient and hygienic and is growing rapidly in popularity, is the portable container. Standard European sizes of two-wheeled bins have capacities of 80 to 240 litres and four-wheeled containers have capacities of 660, 880, 1,100, and 1,500 litres. They are commonly made from plastic but may also be made from galvanised sheet steel. There are many variations within this concept, including containers with capacities between 1 and 3 cubic metres. (Figure 5.3 and Photos 5.3) These containers are emptied by mechanical lifting equipment fitted to the collection truck and then replaced in the same location. One truck, on its collection round, can empty many such containers before going to a transfer station, treatment plant or disposal site to unload.

Wheeled bins are usually fitted with lids, but these lids are generally not used and are often damaged. Some have mechanisms that open the lid when a bar is pushed down by the user's foot, but often these mechanisms are soon broken.

Most containers of this type have four wheels so that they can be manoeuvred to line up with the lifting gear on the truck. (It would take more time to manoeuvre the truck to line up with the bin, and in congested streets it might be impossible to get the truck near enough to a bin that could not be moved by the collection crew. Even if the container has wheels it can be difficult to bring the container to the truck if obstructed by parked cars.) Some containers that are used in this way have strong skids or "feet" on which the containers can be moved if the road surface is smooth.

The conventional system is to empty wheeled bins using compactor trucks that have lifting equipment at the rear, side or front. (Front-loading containers normally do not have wheels because the driver can manoeuvre the truck so that the lifting forks engage the container where it is.) Although this system is widely used in industrialised countries, it may be very unsuitable in some low- and middle-income countries. One problem is the use of compactor trucks, which have proved to be expensive and unreliable in many situations (Sections 2.3 and 7.8.1). Another problem can be that the ground on which the



Plastic tote or "wheelie" bin; 80 – 240 litres

Plastic or steel wheeled container; 0.6 – 1.5 m³

Figure 5.3 Wheeled bins, with capacities from 80 litres to 1,500 litres, can be wheeled out to the collection vehicles which have special binlift attachments. Plastic bins are destroyed if set on fire.

a) This wheeled container is difficult to move on uneven or soft ground, especially when the wheels are damaged because the containers are overloaded by dense waste

b) This container has no wheels and is picked up by a crane that can reach containers on the road verge (See Section 7.6.6)

Photos 5.3 Movable community containers

a) Each bin belongs to one household and shows the address of the owners.

b) The container has a lid, but it is not closed. Containers parked on roads cause traffic problems.

c) This was a 1,100 litre green plastic bin until someone put hot ashes into it. Alternatively, someone may have set its contents on fire because it had not been emptied or for some other reason.

Photos 5.4 Wheeled bins

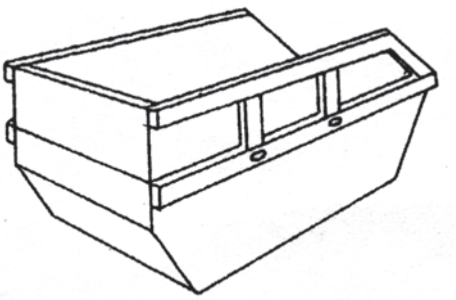
bins are located is soft or uneven, or at a different level from the road. In such cases it can be very difficult to move a bin that is fitted with small wheels. This difficulty is made worse by the high density of the wastes in many developing countries, and the combined effect of these two factors is likely to be that the wheels are quickly broken. Any observation of wheeled bins in such situations shows this fear to be justified – containers quickly lose their wheels, or the use of their wheels, and are further damaged if they are manhandled into position by three men using crowbars. Using bins with broken wheels involves high labour costs, poor vehicle utilization and high replacement costs for the bins. Regular checking and maintenance of these wheels is a better solution. However, if the wheels are serviceable, there is the risk that the containers will be moved to unauthorised locations by members of the public. These bins are also used for improvising barricades and roadblocks during street demonstrations. Small capacity portable containers are also susceptible to being tipped over by waste pickers looking for recoverable materials. The thickness of the steel sheet used to fabricate these bins should be greater where waste densities are higher, to provide greater strength and corrosion resistance.

One solution to these drawbacks was demonstrated very successfully in Gaza[21]. Non-compaction trucks were fitted with hydraulic cranes that could pick up and empty 1 m^3 containers (which were not fitted with wheels) that could located anywhere (even on loose sand) within the 8 metre reach of the crane on the truck. However, this system could not be used in narrow streets or where there was a risk of touching overhead electricity wires. (There is more information about the trucks in Section 7.6.6)

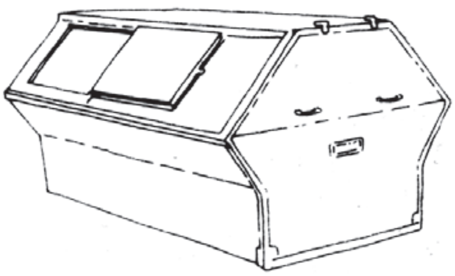
5.3.5 Exchanged containers

The common feature in this category of waste container is that full containers are transported with the wastes inside to a transfer station, treatment plant or landfill, and emptied at this destination. Often an empty container is left next to the full container before the full one is removed (Figure 5.4). Vehicle productivity is maximised since the time taken to set down an empty container and load a full one is very small (sometimes as little as 1 minute if there are no obstructions, such as parked cars), and, with appropriate tipping gear fitted to the vehicle, unloading also takes very little time. Hence, the overall round-trip

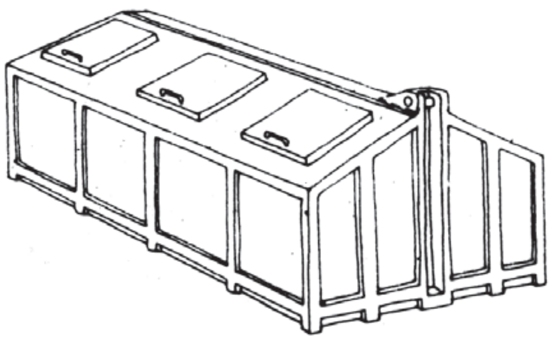
21. Reference [Borno 2000]



4 m³ skip (lugger) container



6 m³ tractor trailer container



10 m³ hooklift container

Figure 5.4 Exchangeable containers are picked up by special vehicles and transported away for emptying. Parked cars can be a problem for vehicle access.

time is, to a large extent, composed of travel time as the vehicle shuttles between container locations and the unloading point. Container system vehicles are capable of making up to five times the number of trips of other collection vehicles. The labour requirement is also minimal when compared with stationary facilities (Section 5.3.3), provided that containers are exchanged before the loaded container overflows. Productivity is also heavily influenced by the amount of waste that is transported on each trip, and sometimes these systems carry significantly less than the vehicle payloads because of restrictions on the size of the containers and the fact that containers are usually picked up before they are full. The durability and replacement cost of the containers must be taken into account in any cost calculations.

Exchanged container systems are used in a variety of ways:

- **As a community container for domestic wastes** – Residents and shopkeepers bring their wastes to the containers. Exchanged container systems come in a range of sizes, and it is very important to select an appropriate size of container (paying particular attention to the loading height), according to the population to be served. Conventional exchanged containers are too big for most situations, and would prove uneconomical because of the small loads carried. Container systems for wastes containing biodegradable material must be operated on a regular schedule with collection at intervals of no more than two days to avoid problems with insects, rodents or smells. (This shorter interval is necessary because the wastes being put in the containers may already have been stored in the households for some time and started to decay.)
- **As the second stage in a transfer system** – On a small scale, wastes collected from houses and shops by small collection vehicles such as handcarts and three wheeler auto-rickshaws can be loaded into exchangeable containers. On a large scale, big transfer operations often use large containers, sometimes with compaction, to transport large quantities of waste over long distances. If the system is operated well, there is always a container available to receive wastes from the primary collection, with no waiting involved. The vehicle that removes the containers may also spend little time waiting.
- **From markets** – Markets usually produce large quantities of waste that are generated continuously throughout the working day. Large exchanged containers can be located at such markets and emptied each evening or more frequently if needed.
- **For industrial and institutional wastes** – Many wastes from industries and institutions are not biodegradable so they can be collected less frequently than household wastes, either on a regular schedule or at the request of the generator. Construction and demolition wastes and some industrial wastes are much denser than municipal wastes, and in such cases care must be taken to size the containers to ensure that the payload is not excessive.

The details of the various systems and mechanisms for lifting the containers are introduced in Section 7.9. There are two basic systems for loading exchanged containers onto trucks[22], and another system is used for container-carrying trailers that are pulled by tractors. Some trucks are designed to pick up and carry two or more containers. Agricultural tractors and smaller machines have been modified to pick up containers and carry them short distances. It is important to ensure that there is always sufficient space around the container so that the vehicle that picks it up can approach the container from the correct angle. This means that such container systems cannot be used in areas where there are parked cars or where the necessary manoeuvring space cannot be guaranteed.

Trailers are also used as exchanged containers. Large trailers can be left at a transfer station for loading while a truck or semi-trailer tractor is taking another trailer to the disposal site. Four-wheeled trailers that are pulled by agricultural tractors may be used in this way, at markets, transfer stations or as community storage, or two-wheeled trailers can be used in this way if they are pulled by a tractor fitted with an automatic pick-up hitch. Typical agricultural trailers have high loading heights and require a ramp or split-level site for convenient loading. However, special low loading height trailers (Photo 7.9) can be manufactured locally. If trailers are left in public places overnight they may be vandalised, or their wheels stolen.

22. *The design of one type of container has been discussed by A K Sarkar [Coad, 1997]*

Box 5.3 — Example

An innovative exchanged container system

A proposal has recently been put forward to introduce a novel "high-tipping container pick-up trailer" into a number of towns for the UN-HABITAT Lake Victoria Water and Sanitation Initiative in East Africa. The high-tipping container trailer will be manufactured locally within the Lake Victoria region and will be able to pick up, transport and discharge both small 4.0 m^3 community containers and 8.0 m^3 capacity transfer containers. The 4.0 m^3 community containers will be deposited throughout the residential and commercial areas of the towns so that residents and shopkeepers can bring their wastes to them. They will normally be emptied when they are around 75% full (with 3.0 m^3 of waste). The 8.0 m^3 transfer containers will be located at the market places and selected transfer points throughout the towns. 60 hp tractors with the high-tipping container pick-up trailers will pick up the 4.0 m^3 containers and, using the special high tipping mechanism, empty them directly into the 8.0 m^3 transfer containers (see Photo 7.23 in Section 7.9.1). The tractor and trailer combinations will pick up the transfer containers when they are full and, transport them to the disposal site and empty them by tipping. The use of the large transfer containers will reduce the number of trips to the disposal site to one third.

It is also proposed to also include a primary collection service within the commercial areas using modified small Chinese two-wheeled tractors (power tillers – see Section 7.3.3) to provide a daily service to the business premises and any households prepared to pay for this service. These two-wheeled tractors and trailers will carry waste in eight bins of 100 to 150 litres capacity. If the household or shop bin at a particular location is nearly full, it will be exchanged for an empty one from the trailer, and bins which are only partially filled will be emptied into one of the bins on the trailer. When all the bins on the trailer are full they will be emptied into the nearest transfer container. The trailer has a flat bed on which the driver and sweeper at the container point can stand when emptying the bins into high-sided containers.

Summary points

- A storage container is a simple piece of equipment but it takes considerable thought to design one that will serve the citizens well and allow a good method of loading of the waste into the collection vehicle.
- The method used to load waste into a collection vehicle should be safe, hygienic, tidy and efficient.
- Household containers can often be lifted and emptied into the collection vehicle manually but better systems for community storage empty the bins mechanically at the point of collection or exchange empty containers for full containers.

6 STREET AND DRAIN WASTES

6.1 THE TASKS

Municipal solid waste management includes street sweeping, emptying litter bins, and sometimes the cleaning of open drains and grass cutting. In developing countries streets are almost invariably swept manually, though some cities have tried using sweeping machines, very often without much success because of inappropriate road surfaces and obstruction caused by parked vehicles.

6.1.1 Characteristics of street and drain wastes

Street wastes are sometimes called behavioural wastes, because their nature and quantity depend very much on the behaviour of individuals. Attitudes to littering (the throwing of wastes on the street or on the ground in open spaces) vary greatly from place to place. In some cultures it is acceptable to throw wastes on the street. Simple observations illustrate the differences: in one country a senior environmental expert was seen to throw waste packaging out of a car window, but in another country ordinary citizens pick up litter that is found on a street, or tell the person who dropped it to pick it up. In Singapore for example, where there is strict enforcement of anti-litter laws, even motorcycles are seen to be fitted with ashtrays with lids. In some countries it is regarded as the normal duty of dog owners to pick up the faeces of their dogs, and there are hygienic systems for doing this. Therefore, an important aspect of the management of street wastes is to educate and motivate the public not to drop unwanted items in public places but rather to put them into street bins or keep them until they can be discarded in an acceptable way.

Street wastes may contain significant proportions of household waste if the collection system for household waste is inadequate or not used correctly. In such cases household wastes may simply be dumped on the street and later swept up and collected by street sweepers. If is much more expensive to collect household and commercial waste in this way than to collect waste that is in bins or bags. Plastic bags that are left out on the street may be torn open by cats or dogs, so that the contents are scattered in the street. Waste pickers sorting through waste to find items that can be recycled often leave unwanted wastes scattered near storage points. The costs of waste collection and street cleaning should be considered together to ensure that the expenditure saved in the waste collection service does not cause a much higher additional expenditure on street cleaning.

Street wastes typically consist of

- sand, silt and clay blown by the wind or scattered from road repairs and building sites, and other abrasive materials from the road surface and vehicle wheels,
- litter and other wastes deposited by pedestrians and householders,
- leaves and other vegetation,
- spilled loads, and debris from vehicle accidents,
- sludge and waste excavated from drains
- animal excreta, and
- small amounts of trade wastes.

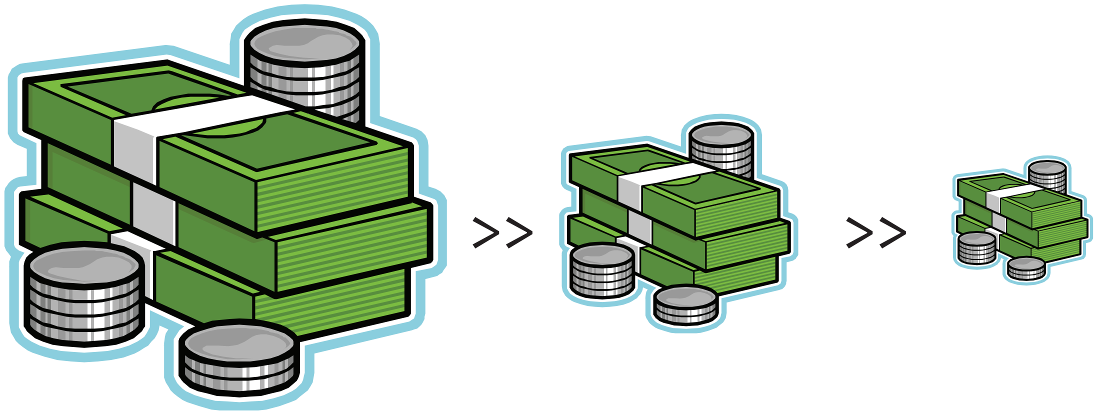
Drain wastes are usually wet and may consist mostly of sand and silt, and so are much denser than other solid wastes. If the drains carry sanitary wastes the excavated silt may have an unpleasant smell and attract flies.

It is unfortunate that many people consider street drains as appropriate places for solid wastes. In fact, drains are the worst places for solid waste. Plastic, soil and organic material in drains combine to form solid obstructions to the flow of water, and these are particularly troublesome in culverts and covered sections where access is difficult. Blocked drains encourage mosquito breeding and cause flooding. Paper and biodegradable wastes in drains lose their strength and cohesion and so are difficult to remove. The depth of some drains makes the cleaning process slow, difficult and even dangerous.

6.1.2 Methods of collecting street wastes

Street wastes are normally collected by being swept by hand into small heaps which are then loaded by hand into handcarts or barrows. The burning of litter on the streets should be strictly prohibited for public health reasons. Street waste that is not collected may find its way into drains. It is more expensive to collect waste out of drains than to sweep it up on the street.

Street sweeping activities should include sweeping up around transfer points and street containers prior to the arrival of the collection vehicles. This may require careful programming of the different activities. Typically, street sweeping crews consist of one or two men or women.



The cost of collecting one ton (dry weight) of solid waste from a drain or canal ***is much more than***

the cost of collecting one ton of waste from the street, which, in turn, ***is much more than***

emptying bins containing one ton of waste directly into collection trucks

Figure 6.1 Comparing the costs of collecting one ton of waste from household bins, from streets and from drains

Generally roads need to be swept only at the sides, because the movement of traffic keeps the central section of the roads free of waste.

Litter bin wastes include plastic and paper litter, drinks cans and bottles, some organic wastes and often some household wastes. Depending on the number and spacing of the litter bins and the frequency of sweeping, they may be emptied by the street sweepers as part of their sweeping rounds or may have a separate collection service.

In many cities street sweeping is combined with the manual collection of household and commercial wastes. In such cases, most of the time may be devoted to sweeping the street, but the majority of the waste is collected from houses and shops, and so the means used for transporting the waste (usually a handcart) must be larger, and more frequent trips to the emptying point will be needed.

Street sweepers and litter bin collectors either empty their loads into the community waste containers or bring them to transfer points, according to the waste collection system in the town or city. Localised secure parking places for the street sweepers' carts are essential to avoid lengthy journeys at the start and finish of the shift and to maximize labour productivity.

6.1.3 Street washing and drain cleaning

In some cities streets are washed. This is done by tanker trucks using relatively high flows of water and is intended to remove dust and animal excreta. This practice requires not only significant volumes of water, but may also overload the gully traps[23] with solids (if they are not cleaned very regularly) and the street surfaces must have good slopes towards the drains without depressions which would cause ponding. In some cities in dry climates, where the streets have no drains, water is sometimes sprinkled to control the dust, but the benefit lasts for only a short time.

Open drains come in many shapes and sizes. Some, that are used for domestic grey water[24], may be less than 15 cm wide. Elsewhere storm drains are large rectangular or trapezoidal drains that may be more than 2 m wide. Some street drains are less than 50 cm wide but more than a metre deep. Some are covered with removable slabs and others are open. The hand tools that are provided for cleaning drains should be shaped to match the profile of the bottom of the drain. Some storm drains also serve to bring irrigation water for roadside trees. Some street drains are fitted with screens to catch solid wastes that are floating in the drainage water; these screens must be cleaned very regularly to avoid local flooding.

Small street drains may be cleaned regularly together with the adjacent street. The cleaning of large storm drains is usually a separate operation undertaken once or twice a year by teams of two to ten men using conventional tipping trucks to transport the wastes, perhaps even using wheeled loaders to load the wastes into the trucks. Sometimes the excavated wastes are left beside the road to dry before being removed. Depending on the local climate

23. Gully traps are fitted at street inlets to subsurface storm drains. Water flows from the street through the gully trap to the underground pipe or sewer, depositing solids in the gully trap so that the drains are not clogged. As a consequence, the gully traps become filled with silt and debris and must be cleaned regularly.

24. Grey water is wastewater from kitchens and bathrooms (but not toilets) that contains relatively little suspended solids.

and rainy seasons, drain cleaning may take place only during short periods of the year and it may be cost-effective to hire in the trucks, tools and even labour for this activity.

6.1.4 Public participation

In some towns and cities residents are requested or required to sweep the pedestrian area or street in front of their houses. In such cases it is important to ensure that they do not sweep the waste into drains. Some cities have weekly or monthly cleanup days when all citizens are expected to clean the streets and open areas in their neighbourhoods. Such periodic cleanups are needed in areas where the sweeping and waste collection services are inadequate, but public participation in this way can also be used strategically to mobilise communities, motivate them to co-operate with the waste collection system and develop a greater sense of responsibility for keeping their neighbourhoods clean. When residents see the benefits that combined action can bring to their communities, they may become motivated to make other improvements, such as improving road surfaces or planting trees.

Emergency cleanups of the kind described in Box 6.1 are organised when there has been a major failure of the solid waste management system, and require more inputs than can be provided by public participation.

Box 6.1 Additional information

Emergency cleanups

There is a tendency for local authorities to operate their waste management services on a crisis management system. Because of a lack of resources and dependence on obsolete equipment, the system deteriorates until collection services break down and there is a build-up of wastes in the city, followed perhaps by a disease outbreak. This leads to government intervention with the provision of a batch of new trucks and the injection of funds for an emergency cleanup. Inevitably this results in a new waste management system which is inefficient and not sustainable, as the next paragraph explains.

The equipment provided is targeted at solving the immediate crisis with an emergency clean-up rather than the longer term challenge of ensuring a sustainable waste management system. As a result, it is not uncommon to find that large trucks and wheeled loaders have been provided to deal with the immediate problems of heaps of wastes around a city, whereas the longer term need is for smaller collection vehicles and perhaps a transfer system. After the clean-up, the long-term collection system is then designed to make use of the inappropriate vehicles that were provided for the cleanup, but they are unsuitable for a proper long-term collection system. Thus an inefficient system is perpetuated.

It is therefore strongly recommended that, if an emergency clean-up is required, it should be done by hiring equipment and sub-contracting the labour so that the local authority can concentrate its resources on the long-term requirements. Equipment should then be provided on a phased basis over a number of years so that this equipment in turn becomes obsolete on a phased basis, with regular small annual budgets for its replacement, instead of repeating the cycle of building up to an emergency situation every few years.

Emergency cleanups of this scale may be implemented in preparation for a new system, such as when a new private sector operator takes over.

6.2 MANAGEMENT OF STREET SWEEPING

6.2.1 Efficiency

Although the type of technology employed in sweeping streets is not sophisticated, it is worthwhile to manage this operation in a thoughtful way because of the large size of the workforce. The amount of work allocated to one sweeper or one team may be defined as an area or a length of street. Usually the movement of traffic keeps the centre of a street clean, so that it is necessary to sweep only the sides of the streets and pedestrian walkways. It is advisable to check this allocation of work from time to time to see whether the amount of work expected from the labourers is reasonable – neither too much nor too little. It is also useful to review the time that sweepers spend waiting to start or sign off, and walking to and from their beats (the places where they work), because excessive waiting or walking have a significant impact on productivity, and therefore on the size of the workforce or the area that is cleaned. If sweepers work in pairs – one sweeping and the other pushing and perhaps loading a handcart – it is useful to observe how the work is divided between them and whether the arrangement is efficient. It is also advisable to review the suitability and condition of the tools (Section 6.3.2) and the handcarts.

Often sweepers are required to improvise their own tools for loading the sweepings into their carts. To load the wastes they have collected into a container, they may be required to tip the wastes onto the ground before picking them up again. This wasteful and unhygienic practice can be avoided by the use of carts that carry two or three bins which can be lifted off the cart and tipped directly into the container. As street sweeping and drain cleaning can account for quite a high proportion of the municipal labour force, to minimize these costs it is essential that the workers are provided with efficient hand tools and handcarts (barrows), but very often it is found that little or no thought has been given to the designs of this equipment (Section 6.3.2).

6.2.2 Safety

The sweeping of busy streets is a dangerous occupation because the sweepers must often work close to fast-moving traffic. This is a particular danger when sweepers are sweeping near the central division in a dual carriageway or split highway. There should be clear warning signs to warn drivers that sweepers are operating in the area – a vehicle or handcart with a large warning sign can be used – and the sweepers themselves should wear bright or reflective jackets or waistcoats. If sweepers are working at night all possible precautions should be taken to protect them from traffic accidents.

6.2.3 Flexibility

Whether the streets are cleaned by a local government workforce or the private sector, there should be a mechanism for providing extra labourers to clean up additional loads of street waste that may arise because of strong winds, festivals and sports events, or seasonal effects such as flooding and the shedding of leaves or other vegetative detritus.

6.3 MACHINES, TOOLS AND EQUIPMENT

6.3.1 Sweeping machines

Mechanised street sweeping must only be considered for situations where there are uniform and well paved streets without parked cars or other vehicles which would obstruct the street sweeping vehicles. Mechanical street sweeping must only be used on streets with concrete or tarmac surfaces as the brushes of the sweeping machines would quickly tear up an unsurfaced road. Most street sweeping machines are designed to sweep against a kerb, so if there is no kerb at the edge of the road, the machines will not be so effective. The brushes on sweeping machines must be replaced very frequently, and the machines are complex, so it is not unusual to see machines that are less than a year old that are not used because of maintenance problems.

There are also small sweeping machines that are operated by a person walking behind them so that they can be used in pedestrian areas. They can be a nuisance in crowded places. Even in industrialised countries where wage costs are high, it is acknowledged that manual methods must be used in conjunction with machines, as, in certain situations, there is no substitute for manual litter picking and a labourer with a broom.

6.3.2 Hand tools

This section describes the different hand tools required for the various activities. In many cases they can be made locally by adapting readily available tools and implements, but too often general purpose brooms, shovels, forks and other inadequate implements are used. It is very seldom that proper thought is given to the hand tools used by the street sweepers, in particular the brooms and drain-cleaning tools. When selecting or designing tools it is important to consider the type of waste to be collected – in particular its density and particle size – and the surfaces from which the waste should be collected – whether surfaces are paved or unpaved or covered with grass, and the shape, size and depth of open drains.

It is not uncommon to see sweepers in developing countries using standard household brooms or badly designed brooms made locally without any thought of the work efficiency of the sweeper and the convenience or ergonomics of the task. There are two basic types of broom that are used for sweeping horizontal surfaces – the stock broom in which bristles are fitted into a horizontal stock which is attached to one end of a broomstick, and the bunch broom in which a bunch of fibres is tied together. These are illustrated in Figure 6.2.

It is worthwhile to hold a broom and consider the sweeping action. A typical household stock broom has a stock about 30 cm wide, although brooms up to 60 cm wide or more are available. (These wider brooms should generally be reinforced by means of metal stays between the broomstick and the stock.) The sweeping action with this broom uses the upper arm muscles to make a sweeping stroke of around 50 cm. Thus each stroke with a small broom sweeps an area of around 0.15 m^2 and the 60 cm wide sweeper's broom covers perhaps twice this area or 0.3 m^2 per stroke, but requires a lot more arm strength. It is possible to exert a downward force on the broom to scour heavy or adhering deposits from hard surfaces. (Sometimes sweepers are given metal scraper blades for this purpose[25].) Soft bristles can be used for collecting dust and stiff bristles for dislodging and moving adhering and dense materials.

In contrast, the bunch broom is used in a circular action. Bunch brooms come in two kinds: some consist only of the bunch of fibres and the other kind has a broomstick around which the fibres are attached, and the fibres are often splayed out so that the cross section through the fibres is relatively wide. Tall bunch brooms

25. *Tools issued to sweepers in Mumbai were discussed by S A Bargir in Chapter A-1 of [Coad, 1997]*

Bunch broom – uses the shoulder muscles in a radial movement. Each stroke covers four times as much area as the stock broom

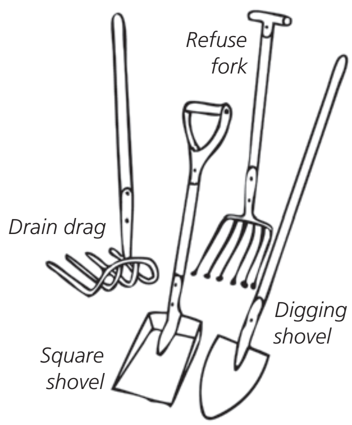
Stock broom – uses only the arm muscles, and covers a small area with each stroke

Figure 6.2 The correct choice of street sweepers' brooms can greatly improve sweeping efficiency

(with or without broomsticks) use the shoulder muscles and typically each stroke covers an area 40 cm x 2.2 m or almost six times as much area with each stroke as the small stock broom and three times the area covered by the wide stock broom. Also, the shoulder muscles are much stronger than the arm muscles and the broom is lighter, so this sweeping action can be maintained for longer periods. It is in this way a much more efficient method of street sweeping. This type of broom is especially suited for collecting light materials such as paper and drinks cans on sandy surfaces where it is not intended to collect the sand. However, the bunch brooms that do not have a broom stick require the user to stoop down, which puts a strain on the back and lowers the head so that the user breathes in more dust than if standing upright. Bunch brooms are much cheaper than stock brooms, even if their shorter life is taken into consideration

Figure 6.3 shows other implements including shovels, special forks and drain drags which are commonly used for street sweeping and drain cleaning. The refuse fork has raised outer tines to prevent waste falling off, and a ball welded to the end of each tine to prevent it from piercing plastic bags, cans etc., which thereby become attached to the tine. A tool similar to the drain drag, but usually with only two tines, is used for pulling large quantities of waste into baskets for loading into containers or trucks. The tools provided to each sweeper should be carefully selected according to the type of work that the sweeper is required to do. In addition, each sweeper should be equipped with a means of collecting up the waste to load it into his cart – two small boards or a scoop are often used. The scoop illustrated in Figure 6.3 is used in the Philippines and is made locally out of flattened 5 litre steel oil cans, with used ball bearings for wheels.

It is recommended that a trial of alternative types of broom and other tools should be made in each city, using locally manufactured tools whenever possible. However it must be appreciated that sweepers who have been using a particular type of broom all their lives have developed their arm or shoulder muscles according to the type of broom they have used and may initially show a preference for what they have become accustomed to, so it may be useful to continue the trial for some months. The type of surface to be swept and the results that are desired must also be considered.



Hand tools

Wheeled scoop made from light sheet steel

Figure 6.3 Equipment used by street sweepers and waste loaders

Box 6.2 Example

Thinking about bunch brooms

In Faisalabad City in Pakistan, for example, the bunch brooms are made from locally grown reeds and each sweeper gets his broom directly from the broom manufacturer, who adjusts the length, the thickness and the angle of the sweeping end to suit each person. This is considered to be the most efficient sweeping operation we have studied. It is also interesting that the City of Paris in France now sweeps its streets with a plastic version of the old fashioned bunch broom having reverted back to this system after having used stock brooms for many years. (Photos 6.1)

If a high standard of cleanliness in crowded places is desired, it may be necessary to employ litter pickers who collect individual items of waste and put them into a sack. Often pincer arms are used so that litter can be picked up from the ground without bending down. Otherwise gloves might be considered, provided that they can be worn comfortably all day and do not cause difficulties in picking up small items.

A small amount of attention to the tools used by the sweepers may double or even treble their efficiency. Drain cleaning tools should be appropriate for handling wet, fine and dense material, and should suit the width and bottom profile of the drains. Consideration should also be given to the repair or replacement of tools that are worn out, damaged, or lost. It was the practice of some private contractors in India to require employees to buy replacement tools with their own money, and though this encouraged them to take care of their implements, it was an added financial burden for staff who were paid little, and probably resulted in them using worn-out equipment that was inconvenient and inefficient. Alternatively, if replacements are readily available, labourers may sell their tools to increase their incomes. A reasonable compromise is to require worn out tools to be handed over before replacements are issued, or to issue and reclaim tools each day.

6.3.3 Handcarts

Poorly designed or badly maintained handcarts or barrows result in low labour productivities and consequently excessive labour requirements. Figure 6.4 shows three designs.

The required capacity of a handcart depends on the volume and density of the waste that is collected in a shift and the distance to the unloading point. The amount of time spent in unproductive travelling should be minimised. If the bins on the handcart are emptied into community containers that are located at frequent intervals, it may not be necessary to carry the collected waste very far, and small carts would be acceptable. Smaller bins should be used if the waste is mostly dense sandy material, so it is not difficult to lift the bins to empty them.

There are many factors to consider when designing a handcart[26], among them:

- **Wheels** – diameter, width, bearings and running surface. Ball bearings and pneumatic tyres are needed for heavy loads, but punctures can be a serious problem. The wheel design depends not only on the weight carried but also on the street surface. Figure 6.5 illustrates a simple way of making handcart wheels using the bead section of a used truck tyre as the tyre. Carts may have one, two, three or four wheels.
- **Weight and durability** – it is easy to design a very heavy cart, but cost and convenience require the weight to be the minimum that does not sacrifice durability. The bins that it carries should be durable or economical to replace.
- **Manoeuvrability** – (important in narrow lanes and congested areas), stability, and ease of parking (so that it does not roll away when left unattended).
- **Ergonomics and convenience of operation** – particularly a convenient handle height to avoid stooping, minimal requirement for lifting force to be provided by

26. *For more information on handcart design the reader is directed to references [Rouse and Ali, 2002] and [Hathway, 1985]*

Figure 6.4 There many different types of street sweepers' handcarts which can be fabricated locally. (Each of these designs has drawbacks as well as advantages)

the operator, and ease of removal of bins. The wheelbarrow on the left of Figure 6.4 requires a considerable lifting force if heavily loaded and is very unstable with high loads. However its cost is low. Bins (as in the cart in the centre of Figure 6.3) allow quick and hygienic transfer of the collected waste. The capacity of the cart must be sufficient so that time and effort are not wasted in frequent journeys to empty the cart. In an Indian city some of the women waste collectors have become permanently deformed by having to bend down low while pushing heavy handcarts with very small wheels unsuited to the poor road conditions. The man who designed these carts should be made to push one himself for several hours before being obliged to redesign them. (Photo 6.1.b)

- **Prevention of theft** – sweepers' carts are often left in public areas; in such cases theft should be prevented (particular of containers, which may be stolen for recycling or other purposes).

The maintenance of handcarts is important, both to ensure their operational efficiency and to project a good public image of the solid waste management service.

Handcarts should be fitted with hooks, and perhaps a box, so that tools can be carried conveniently and safely.

6.3.4 Litter bins

Litter bins are provided at regular intervals in streets where there are many pedestrians and where there are no community bins into which passers-by can drop unwanted items. They may have little impact unless accompanied by anti-litter legislation, enforcement and public education. If an area is kept clean, pedestrians may be reluctant to be the first person to drop litter, whereas if there is already scattered litter in a public area, people may consider it normal to add to this waste. The spacing between bins and the frequency at which they are emptied can be determined by observation and experience.

It may seem an easy task to design and manufacture a litter bin, but many existing designs show weaknesses. Maintenance and replacement of bins is essential because of vandalism, fires, corrosion and other hazards. A good litter bin has the following features:

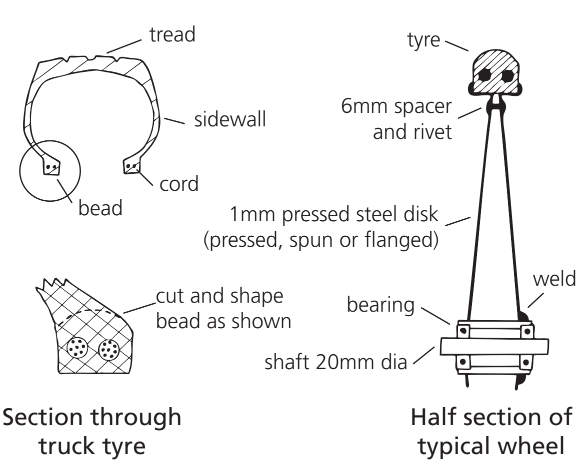


Figure 6.5 A simple handcart tyre made from the bead of a used truck tyre

a) Sweepers carts

b) Badly designed cart (see also Section 7.3.1)

c) Paris sweeper

d) Faisalabad sweeper with broom (Box 6.2)

Photos 6.1 Street sweeping

- **Appearance** – It should be neat, clean and easy to see, and it should not be possible to confuse it with a letter box! Some attractive designs in public parks are shaped in the form of animals – the shape of a frog is particularly suitable. Bins can be sponsored by local companies which are allowed to display their names and logos in an agreed manner. Slogans about using the bins and keeping the streets clean are often displayed. Some authorities require surfaces that make it difficult to cover the bins with unauthorised advertising posters and graffiti.
- **Wind and rain** – It should not be possible for the wind to scatter light materials that have been discarded into the bin, and in many climates it may be advisable to have a cover that keeps off the rain. Some bins have wire baskets or holes in their base so that liquids can drain out. It should not allow cats and dogs to enter it.
- **Fire** – Discarded cigarettes may cause fires if dropped onto dry paper. If this is a common problem plastic bins are unsuitable.
- **Emptying** – It is common to see labourers emptying containers by putting their hands into them and pulling out the waste. This entails too high a level of risk, and so it should be convenient to empty the litter bins without coming onto contact with the waste. One option is to install bins that are pivoted about a horizontal axis so that they tip to empty. They must be designed so that there is space underneath for a container to catch the waste and so that the top of the container is not too high above the ground. Another option is to use bins with internal baskets or containers that can be lifted out for emptying. These internal baskets may be stolen if they are not locked into position.

Litter bins have sometimes been used to hide terrorist bombs. In situations where such actions cause concern, the litter bins should be replaced with transparent plastic bags.

Photo 6.2 Pivoted litter bin that can be tipped to empty it

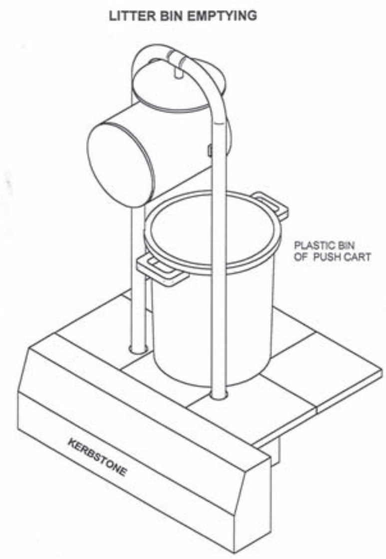


Figure 6.6 Emptying a pivoted litter bin

Summary points

- Drains are the worst places in the world for solid waste because of the cost of removing it.
- If household wastes are badly managed, they become street wastes.
- Without good management and appropriate tools which are kept in good condition, street sweeping can become very inefficient.
- Public behaviour has a major influence on the demands put on street sweeping.

7 SELECTION OF WASTE COLLECTION VEHICLES

This long chapter contains a large amount of practical information regarding the wide range of vehicle combinations that are used for collecting waste. First (Section 7.1) come the general factors that should be considered when selecting vehicle types are reviewed. Section 7.2 discusses the selection of the appropriate size of body. Sections 7.3 to 7.9 review and compare the many different kinds of vehicles that can be used for solid waste collection, many of which are shown in Figure 7.1. Section 7.10 presents a brief summary.

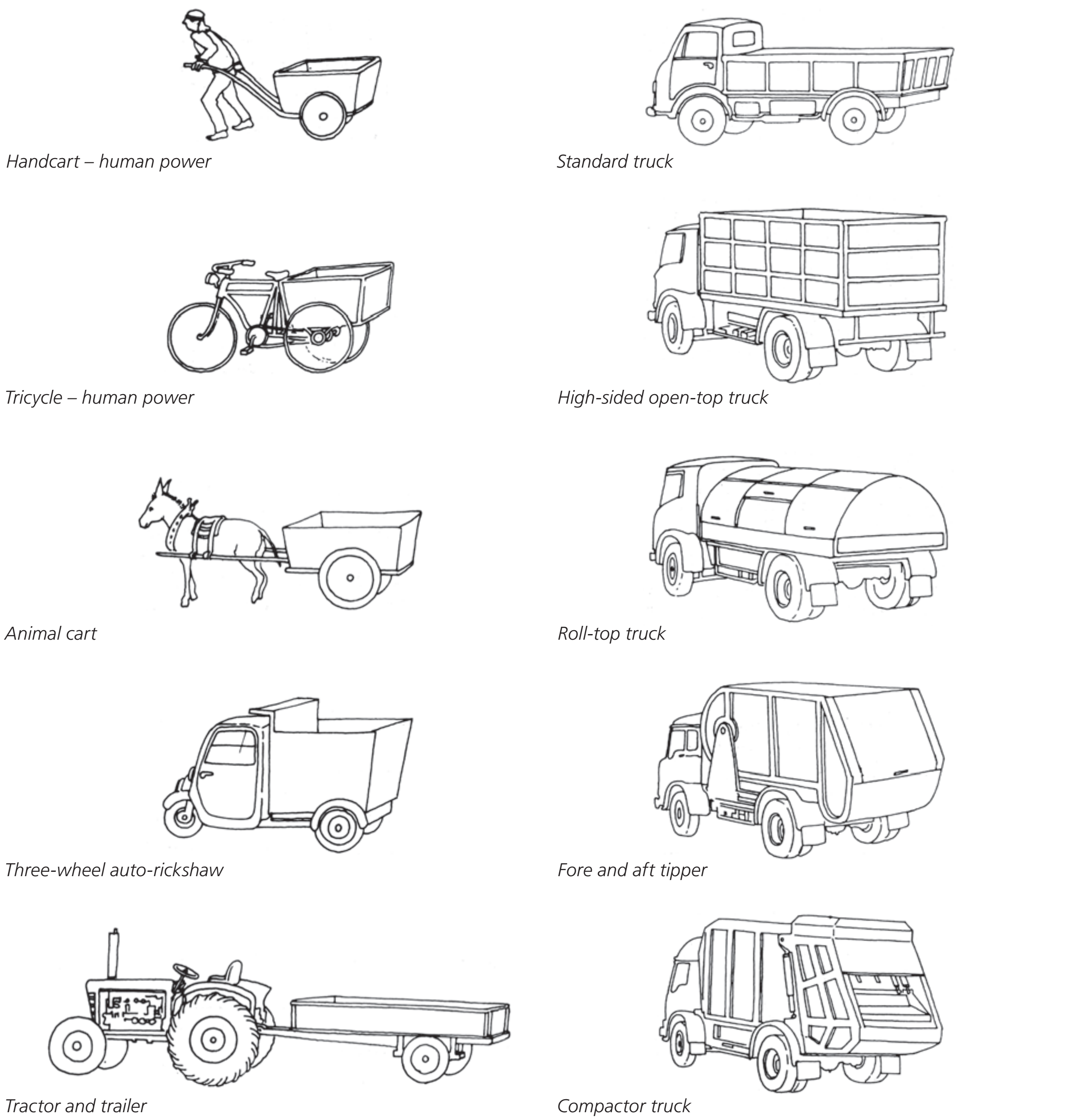


Figure 7.1 Waste collection can use manpower, animals, tractors or trucks of different types and sizes

7.1 FACTORS TO CONSIDER WHEN SELECTING VEHICLE TYPES

This Section is mostly concerned with the technical and rational reasons for selecting particular types and makes of vehicles and equipment. Unfortunately, decisions regarding the waste collection vehicles that are supplied are often made by executives who have very little understanding of technical issues. Decisions are too often based on factors which are not related to the operation and performance of the vehicles. Corruption and personal relationships sometimes lead to inappropriate vehicles being ordered. In an attempt to avoid corruption, the selection of the lowest bid also sometimes results in unreliable and inadequate vehicles being purchased. Vehicles provided by donors are sometimes of an inappropriate design and from a manufacturer which is almost unknown in the region where these vehicles are expected to be maintained. Local politicians are usually happy to receive large, shiny and sophisticated vehicles and to be videoed with them. However, not long after, when the vehicles are non-operational, it is often the workshop manager or the city engineer who is accused of inefficiency and corruption that have led to the failure of the still-new machines.

Many technical factors have a direct bearing on the selection of a collection system and vehicle for any particular situation. In many cases the choices of vehicle and storage system are interrelated. This section describes the main factors which should be considered before selecting the preferred type of waste collection vehicle, bearing in mind that the objective of any waste collection system is to collect and transport wastes from specific locations at regular intervals to a disposal site at minimum cost. On average, transport capacities of 100 to 300 m^3 per day per million people served are provided in developing countries[27]. Costs include two elements: operating costs (comprising labour, fuel and maintenance) and capital costs (including depreciation and interest on capital). In industrialised countries, labour wage rates are high, and, hence, the ratio of labour costs to vehicle cost (including capital amortization) is usually high. In developing countries, the converse is usually true, vehicle costs being the largest proportion of overall system costs. This explains why priority should be given to optimising vehicle productivity in preference to labour productivity, i.e., to maximising the total tonnage of waste transported per vehicle per day in preference to the total tonnage of waste collected per worker per day (Figure 7.2). In the final analysis, the most economic combination of vehicle and workforce is indicated by comparing the cost of collecting each ton of waste (all costs being considered), but these costs will reflect the importance of vehicle productivity in developing countries. The sample calculations in Annex A3 illustrate this point.

The factors discussed in the following sections should all be considered before a shortlist of possible vehicle types is prepared.

7.1.1 Waste generation rate

It is a general rule that more affluent countries and communities generate more waste. Countrywide average rates of waste generation in most industrialised countries lie between 0.8 and 1.4 kg/capita/day. In developing countries the average generation rate is generally within the range of 0.2 to 0.4 kg/capita/day, but the actual generation rate varies greatly between different parts of any city, and may be as low as 0.1 kg/capita/day in the low-income urban areas, the generation rates in such areas being as little as one half the citywide average.

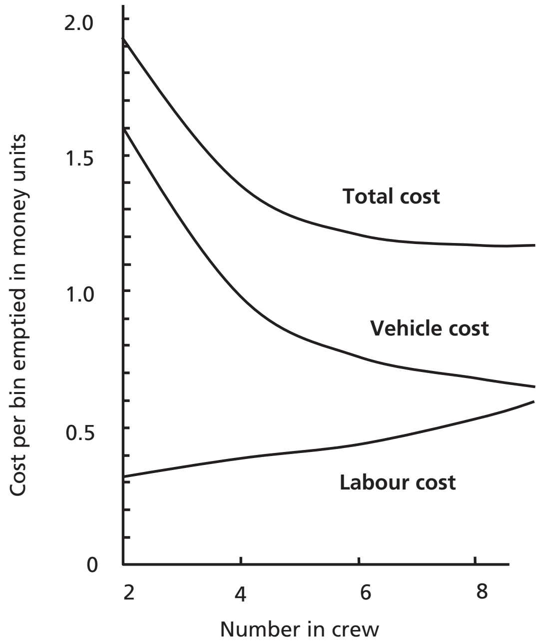
The rate of waste generation has a significant influence on the choice of collection system and vehicle. For example, if an assessment is made of the comparative productivity of a refuse collection vehicle undertaking kerbside collection in two communities, where the rate of waste generation in the first is half that in the second, it is evident that, in order to carry the same final payload to the disposal site, more stops will be necessary in the case of the first community. Vehicle productivity will, therefore, be reduced, and alternative systems, such as the use of portable community containers can prove more productive in such a case.

7.1.2 Waste density

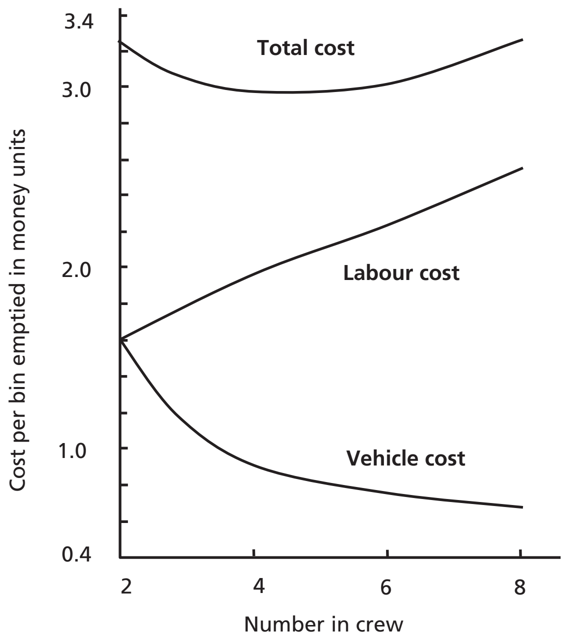
It is common for consultants and project teams to spend a considerable part of their investigations by undertaking full waste surveys, concentrating mainly on measuring the proportions of various categories of material in the waste. However, for the purposes of planning the collection service, the basic requirements are to know the weight of waste to be collected each day and its density, so that it is possible to calculate the volume of the wastes and the size of the truck body required for the most economic loads, without overloading.

Waste densities differ considerably, depending on the relative affluence of the community and many other factors, and the density of a particular sample of waste changes according to the way in which it is handled and stored, as discussed in Section 3.2. The types of vehicle

27. *Reference [Cointreau, 1980]*



For a low ratio of wage rate to vehicle cost – 1:10 – large teams achieve the lowest cost



For a high ratio of wage rate to vehicle cost – 1:2 – small teams achieve the lowest cost

Figure 7.2 Optimisation of refuse collection crew size for door-to-door collection **Source: Flintoff (1976)**

to be used for refuse collection, and hence the method of collection should, to a large extent, be determined by the density of the wastes in the truck body. This density may be very different from the density at the household or in the community container, even if the truck has no compaction mechanism. The only data relevant to the selection of the vehicle is the density in the vehicle body, which can be estimated by measuring and weighing randomly selected truck loads. It is, therefore, essential to have reliable data on waste density before starting to plan a refuse collection system.

Where waste densities are low, as in industrialised countries, it is necessary to compact the refuse to increase its density and reduce its volume, in order to maximise vehicle productivity by the transporting of maximum payloads. It is for this reason that compaction vehicles are used throughout these countries. Compactor trucks are typically designed to compact light refuse, having a density of around 100 kg/m^3, to a compressed density of up to 500 kg/m^3, so that the truck can carry a full load. In contrast, the naturally occurring density of waste in developing countries is usually in excess of 300 kg/m^3, and often much higher, so there is no logical or practical reason to require compaction for such wastes. Despite this fundamental difference, it is common to find that consultants from the industrialised countries have recommended the use of compactor trucks in situations where they are totally inappropriate, resulting in costly, short lived and unsustainable systems.

Refuse density also changes with location, method of storage, frequency of collection and season of the year. The density of a sample of solid waste can have significantly different values in the household, in a community container, in an open truck and in a compactor truck. These variations are caused by many different factors including evaporation, decomposition, compression by self weight in the container, scavenging by animals or people, and air entrainment or release during handling, loading, compaction and travelling. Refuse which is relatively light where it is generated will increase in density during storage owing to consolidation under its own weight, as new material is added and, with time, as a result of the partial degradation of organic matter. Refuse in a plastic bag that is tied closed has a lower density than the same waste in a paper bag because of the air trapped in the plastic bag. Refuse density is higher in the rainy season than in the dry season. Refuse density in community containers is often greater than in household containers since opportunities for waste consolidation are greater in larger containers. Similarly, waste consolidation takes place during transport. It is common to note a 20 to 25% increase in density as waste is transported in non-compaction trucks. It is, however, possible, in some cases, for waste densities to decrease during the process of transferring from a storage facility to a collection vehicle. Such a reduction was observed in Karachi, when waste stored in community containers was transferred to roll-top collection vehicles by raking it into baskets (Figure 3.1). Air entrainment during the transfer process was responsible for the reduction in waste density. Clearly, vehicle productivity could have been improved by the use of portable communal containers which, when full, are lifted onto a truck and transported directly to the disposal site.

These trends are shown in Figure 7.3, which is a nomograph enabling the estimation of waste density for a particular sample of waste at the different stages of collection. A measurement of waste density at one stage (for example, community storage) can be used to estimate the density at another stage (for example, when loaded into a particular type of truck). Such estimates can then be used to estimate the capacity or size of containers or collection vehicles required. To use this nomograph:

a) Take the known density data and draw a horizontal line from that density on the vertical axis to the line dedicated to the place of measurement (household, container or truck).
b) Draw a vertical line up or down from that point of intersection till it meets the line dedicated to the type of truck or container for which the density is required.
c) Draw a horizontal line from this new point of intersection back to the left hand vertical scale and read off the estimated density. For example, waste which has a density of 350 kg/m^3 in the household bin may reach a density of 630 kg/m^3 in a community container.

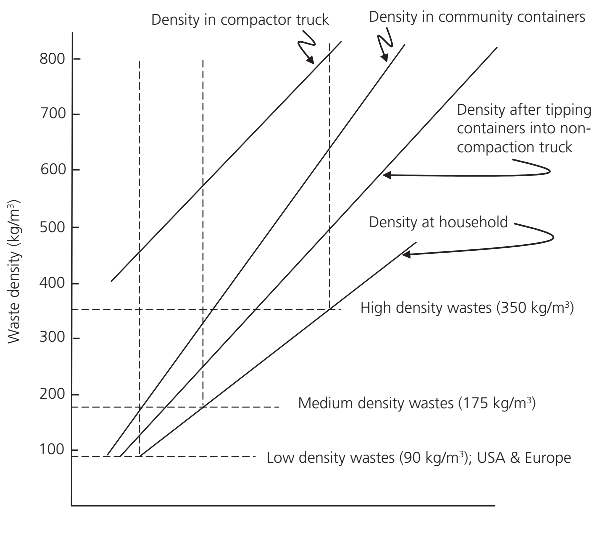


Figure 7.3 Example of changes in waste density during handling

It must be emphasised that this is only a preliminary indication and that different results would be obtained from different waste types and locations. Its main value here is to indicate the importance of using a value of waste density that applies to the stage in the collection system that is being considered.

7.1.3 Waste volume per capita

It must be understood that the combination of lower waste generation rates (kg/capita) and higher waste density kg/m^3 will both contribute to making a huge difference in waste volumes. For example; – comparing a situation in a developing country with a waste generation rate of 0.2 kg/capita/day and a waste density of 500 kg/m^3 with a high-income industrialised country with a waste generation of 1.5 kg/capita/day and a density of 100 kg/m^3 it can be seen that the per-capita volume of waste to be collected in the high income country will be almost 40 times[28] that of the low income country.

Any waste studies should take into consideration any projected increases in the amount of wastes which will be generated in the future, allowing for urban population growth, additions to the areas to be serviced, and increases in per capita waste generation rates and reductions in waste densities as standards of living improve.

7.1.4 Waste constituents

Up to one third (by weight) of municipal wastes in developing countries may consist of abrasive materials such as sand, stones, dust and ash. Where roads are unsurfaced, poorly surfaced or unprotected by kerbs, sand is carried into the houses on the feet of the inhabitants and is then swept up and ends up as refuse. Likewise, road sweepings from inadequately surfaced roads generate a considerable quantity of inert abrasive materials. The amount of ash in wastes is determined, to a large extent, by the choice of fuels for heating and cooking – where wood, coal or charcoal is used a considerable quantity of ash can be expected in the wastes.

Abrasive materials in waste, such as sand and ash, wear out sliding parts and exposed hydraulic components of refuse collection vehicles. Vehicles, such as compactor vehicles, that are fitted with such features require high levels of maintenance and frequent replacement of sliding and rotating components that are in contact with wastes which contain large proportions of inert materials. Vehicle choice in such cases should be biased against vehicles that are fitted with components likely to be affected by abrasive materials.

28. Developing country: Volume = weight / density = 0.0004 m^3 or 0.4 litres. Industrialised country: Volume = 1.5 / 100 = 0.015 m^3 or 15 litres

Solid wastes in developing countries often also contain a high proportion (40 to 60%) of biodegradable matter, such as remains of vegetables and other foods, which, in hot and humid climates, decompose to produce acidic compounds. Acids thus produced can cause serious problems of corrosion in collection vehicles and in steel containers. Vehicle design, selection and operation must take account of this. Solid wastes from offices can be expected to have low proportions of biodegradable and abrasive wastes, and there is likely to be less abrasive waste in areas that are fully paved, so the wastes from central business districts are likely to be very different from the wastes in the less affluent residential areas.

Depending on the method of waste storage and the level of affluence, the solid wastes from a particular community might be composed of small loose pieces or large bulky items. Air is often trapped in plastic bags containing solid waste so that the wastes require more volume than expected, resulting in a lower overall (bulk) density. Vehicles suited to handling waste in plastic bags are different to those best suited to carrying loose wastes that were stored in non-disposable containers. In general, waste from industrialised countries contains more large items than waste from developing countries and requires specialized equipment and vehicles for collection.

7.1.5 Transport distance and road conditions

Road surface conditions, traffic density and overall haul distance have an important influence on vehicle choice and also affect any decision about using transfer stations. The conditions at both the collection and disposal sites must be evaluated. There is little point in using costly high-speed vehicles with high fuel consumptions in situations where haul distances are short and traffic speeds are slow, making lower powered and lower cost vehicles more efficient. The choice of any collection vehicle must be a compromise between its efficiency when collecting and its efficiency when transporting the waste to a transfer, treatment or disposal site.

The haul distance between the collection area and the unloading point determines the relative importance of vehicle size and road speed. Small, manoeuvrable and easy-to-load machines need to be compared with large, cumbersome machines which might be slow to load but need to make fewer trips to the disposal site. The overall haul distance also determines the need for transfer stations (see Chapter 8) to transfer wastes from small and manoeuvrable vehicles to large trucks, containers, rail wagons or barges for transport to distant disposal sites.

7.1.6 Loading heights[29]

The loading heights of different vehicles have a significant effect on the speed of loading and consequently on vehicle productivity. Excessive loading heights increase the health risks faced by the workers who are exposed to the dust and the micro-organisms from the wastes during loading. Loaders should never be asked to load wastes above their shoulder height due to the excessive work loads and the health hazards of wastes falling onto their heads. This consideration is discussed further in Section 7.2.2.

7.1.7 Traffic conditions and restrictions

The density of traffic in any city or town determines the speed of road traffic, which in turn affects the type of vehicle most appropriate for the conditions. In some cities there are restrictions on the use of large trucks during daylight hours, or during periods when traffic is particularly heavy. Large trucks may be banned from using certain streets or bridges because of weight limits, traffic congestion or pollution.

7.1.8 Local manufacture and sustainability

A key element of sustainability in any solid waste management system is the rapid supply of spare parts and access to maintenance facilities for the vehicles and other equipment being used. Inevitably, if complex and specialised imported vehicles are used, there will be long delays and high costs in the procurement of spare parts as these vehicles wear or break down in the future.

Probably more solid waste management projects have failed because of a lack of spare parts and the associated long delivery times than from any other cause. It is not uncommon to find that 50% or more of a municipality's fleet of vehicles are broken down at any time awaiting delivery of imported parts which have been delayed by the lengthy procedures involved in:

- obtaining quotations for the parts from overseas,
- approving the finance and issuing the purchase order,
- getting authorisation for the foreign currency required,
- obtaining the required letters of credit,
- obtaining import licences,
- getting delivery of the parts,
- obtaining finance for import duties,
- clearing customs, and
- fitting the parts.

29. *The loading height of a refuse collection vehicle is the height above the ground above which a container of waste needs to be lifted so that it can be emptied into the vehicle. It may correspond to the height of the sides of the body, but if waste can be passed up more easily by opening a flap or door, the effective loading height is reduced, at least for part of the loading stage.*

This may result in delays of six months or more in getting vehicles back into operation after even a minor breakdown. Delays of a year or more are not uncommon.

In almost every country, simple, locally manufactured bodies on commonly available truck chassis provide the most sustainable collection systems, as well as benefiting the national economy and local industrial sector. This chapter describes many alternative body types which can be manufactured locally by existing industries which are already involved in building truck bodies or agricultural trailers. High standards of design and construction are important in every case, and it is advisable for the first of a new series of vehicle bodies (the prototype) to be designed and constructed under close supervision, tested under normal working conditions and modified as necessary, before other bodies are constructed and fitted.

All operating and financial costs of the vehicle and associated containers (including depreciation) must be taken into consideration when calculating the comparative costs of different collection systems for a particular situation. (Section 7.1.13 describes a computer program that can be used for this purpose). The operating costs should include the costs and loading speeds for the alternative collection vehicles with different crew sizes. When comparing crew sizes any existing agreements with the local labour union must be taken into consideration.

7.1.9 Level of service and willingness to pay

If all of the costs of the solid waste management system are to be paid from a service fee, the householders' willingness to pay for the service will determine the level of service that can be provided in a sustainable way. This willingness to pay can be expected to be different for different income groups, though the differences may not always be what might be anticipated. This is also referred to in Chapter 10. An effective collection system based on community containers which are emptied every three days provides an adequate but low level of service. A high level of service would involve collecting directly from each house or business every day, but would have much higher capital and operating costs for the vehicles. In between these two levels of service there are many alternatives, as described in Section 4.3. In each situation, if the system is to be financially sustainable the generators (households, shops and businesses) must be willing to pay the costs incurred, either directly (as a waste management fee) or indirectly (by means of a general service tax).

7.1.10 Use of external advisors

Very often when development aid agencies or outside funding sources wish to set up waste management systems they bring in external advisors from overseas to advise on the systems to be used. In many cases these advisors base their recommendations on their experience in their own more industrialised country, without taking into account the different waste characteristics, different street conditions and different labour and capital costs and maintenance capacity. In particular, any advice which is not based on an investigation of local data – such as measurements of the waste density, and investigations of the labour market (including the willingness to work in solid waste management), as well as any projected changes in the future, and the transport distances from different parts of the city – should be treated with great caution and not accepted without further investigations.

Too often also salesmen with an interest in promoting a particular type of equipment take on the role of advisor.

7.1.11 Labour involvement in decision making

Wherever there are labour unions representing the workers, their inputs and those of the workers themselves should be sought before any changes, in particular in the types of vehicles to be used and the size of any truck crews, are made. The crew accommodation on the trucks must be related to the crew size. They may also have useful suggestions for improving the way that the work is done, based on their first-hand experience.

7.1.12 Transportation used in other sectors

It is often useful to observe the types of vehicles, and the makes and models of truck chassis, that are used locally in other sectors, such as public transport, goods haulage and agriculture, when selecting the most suitable vehicle type. If handcarts, tricycles or animal carts are commonly used for carrying loads of all kinds, it may be appropriate to use similar vehicles for collecting solid waste also, though it will usually be necessary to improve on or modify the local design. Obtaining spare parts for motor vehicles from abroad can be a major difficulty for managers of vehicle workshops, so it is essential to select chassis for which the spare parts are available locally.

7.1.13 Computer software for vehicle selection

A computer can be a useful tool for making the calculations needed to compare possible collection systems and for determining equipment requirements. A computer model can be set up for a particular situation using a spreadsheet program (as has been done for the example in

Annex A3), or a general and more sophisticated program (such as WAGS described below) can be used. The main advantage of using a computer in this way is that it is very easy to change items of input data one at a time and note the impact of this change on the output recommendations. There are two dangers to avoid when using computers for such purposes:

- Too much confidence may be placed in the output. Any program that models a waste collection system requires a considerable amount of data, and if the input data are inaccurate, the output may be of little value and lead to bad decisions. Care should be taken to ensure that input data are reliable, and if there is uncertainty about any item, the sensitivity of the final result to variations in this item should be determined. If the output is found to be sensitive to this item of input data, more work should be done to determine a more accurate and reliable value before the output of the computer calculation is accepted.
- The logic of the computer program must be correct and appropriate. Computer programs designed for different locations may not be suited to the particular conditions being considered. Errors in "home-made" programs may be hard to detect unless computer outputs are compared with the results of manual calculations.

The UNCHS-Habitat (since renamed UN-HABITAT) Waste Guidance System (WAGS) computer software was developed to assist with the selection of the most cost-effective waste collection system for any location by matching the most appropriate collection vehicle to each local situation.

The program asks for around 50 inputs relating to the local situation, including population densities and growth rates, waste generation rates, waste density and constituents, travel distances and road surfaces, street widths and traffic speeds. Cost information includes labour, fuel, interest rates, taxes, and import duties, and shadow factors are included for economic costing. From this it builds up a local data base.

The program then asks for a further 50 inputs concerning each vehicle being considered and provides 20 year projections for vehicle and equipment requirements, including life expectancies, operating, fuel and maintenance costs, financial projections for using that type of vehicle in the particular location and discounted economic costs.

The original DOS program has been used very successfully in many countries for analysing all the different collection and transfer options and comparing the financial, operating and economic costs of different systems. However it was found that it requires quite a high level of judgement for some of the inputs and a number of small inaccuracies (or poorly judged inputs) can have a relatively large cumulative impact on the final conclusions. (For example a difference of 10% in each of a chain of six inputs can result in a total variation of as much as 75% in the final calculations.) It was thus very susceptible to misuse by unscrupulous salesmen trying to promote their own particular types of equipment, and for this reason it has not been widely distributed.

It is planned to produce a new *Windows*-based version of this program which will have built-in safeguards to prevent improper use and to restrict the cumulative effect of multiple inaccurate inputs.

7.2 DIMENSIONS AND CAPACITIES OF VEHICLE BODIES

There are many alternative types of collection bodies, and most can be bought or constructed in a range of sizes. The GVW or *gross vehicle weight* is the maximum permitted total weight for any fully loaded vehicle and for reliable performance, and to comply with the law, this should never be exceeded (Figure 7.4). When the weight of the cab and chassis is subtracted from the GVW the remaining weight is the total weight available for the body and the load. From this must be deducted the body weight to arrive at the payload (the maximum weight of the load that may be carried). For economic operation, the load actually carried should be as close as possible to the payload, and the payload should be as large as possible. The lighter the body, the heavier the payload, and, if the load carried is equal to the payload, the lower the cost of collection.

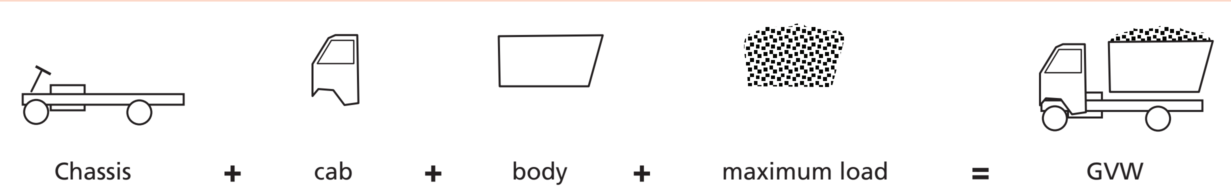


Figure 7.4 The components that make up the gross vehicle weight

7.2.1 Payloads and gross vehicle weight

The required volumetric capacity of the body is calculated by dividing the payload by the density of the wastes in the body. Consequently, the higher the waste density, the smaller the body that is required to achieve the maximum tonnage that the vehicle may carry. Although there is a tendency for decision-makers to ask for compactor trucks in the mistaken belief that this is the "modern" solution to waste collection, in developing countries the full load capacity of the vehicle can generally be achieved without compaction. The extra weight of the compaction mechanism reduces the payload and the additional capital and maintenance costs of the compactor truck cannot be justified. Almost invariably, in developing countries where waste densities are in excess of 250 kg/m^3, there is no logical reason for using compaction vehicles because payloads with non-compaction vehicles can be higher and the capital and maintenance costs of the non-compaction trucks are lower.

The specifications for the most cost-effective vehicles and the capacities of the bodies to be fitted to them depend on a number of factors including road conditions, widths of streets, haul distance, waste characteristics and the method and frequency of waste collection. They will also depend on local regulations governing maximum permitted gross vehicle weight (GVW) and permitted or practical axle loading[30]. Gross vehicle weights of up to 16,000 kg are permitted for vehicles with a single rear axle in most industrialised countries, and the typical weight distribution of such a vehicle is 10,000 kg on the rear axle and 6,000 kg on the front. These loadings are permitted for smooth roads with good road foundations. This is rarely the case in developing countries. Many countries restrict gross vehicle weights and axle loads to a maximum of 13,000 kg and 8,000 kg respectively, to prevent damage to the road. Although heavier loads can be carried by using tandem rear axles, this system is rarely used in developing countries because of the increased capital, operating and maintenance costs involved with higher fuel costs and accelerated tyre wear. Excessive axle loads result in high road maintenance costs and damage to water and sewage pipes underneath the roads.

Solid waste vehicles work in difficult conditions, often driving on roads that are in poor condition and on waste disposal sites. In the desire to maximise the payload, it is necessary to ensure that increased loads are not obtained at the expense of structural damage to the chassis and excessive wear and tear. Saving weight by reducing the strength of the body and the tipping gear can be a false economy if it results in frequent repairs. Consideration should also be given to seasonal and random variations in waste density, and the need to avoid serious overloading when the waste density is highest. If weighbridges are not used on a regular basis, it is worthwhile to weigh loaded vehicles from time to time to check that they are being used economically but not seriously overloaded.

7.2.2 Loading height

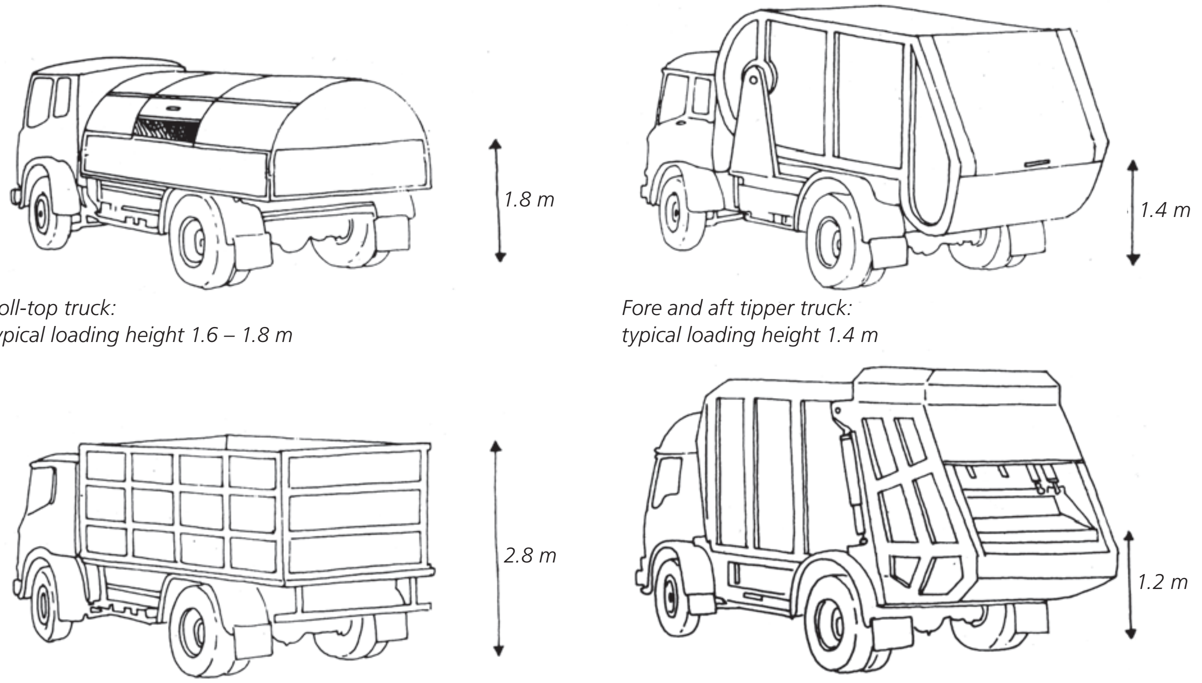
The waste collectors should never be expected to load waste above their shoulder height (typically 1.5 metres) to avoid the health problems caused by wastes falling onto their heads. However, wastes enclosed in small plastic bags can be thrown up to heights of 1.8 metres. High loading heights increase loading times and so reduce vehicle efficiency.

Small collection vehicles (such as human-powered and animal-powered vehicles, three-wheeled auto rickshaws and micro trucks) all have low loading heights, typically less than 1.4 m and so they are easy and fast to load. In contrast, conventional high-sided, open trucks are extremely difficult to load, and the operation is unhygienic and dangerous to the health of workers and passers-by (see Figures 7.5 below and 7.11 in Section 7.6.1). Vehicles with high loading heights may require extra workers inside the vehicle body to receive the wastes and spread them evenly throughout the body (see Photo 7.10). This can be a hazardous and unpleasant task. Table 7.1 compares trucks with different loading heights. Amongst the large-capacity vehicles, the rear-loading compactor truck has the lowest loading height and so it is both fast and easy to load. Sometimes, this type of collection vehicle has been specified for use in developing countries solely on account of its easy loading, although it is often totally unsuited in every other respect. The fore-and-aft tipper vehicle (Section 7.6.4), on the other hand, has a moderate loading height and has the advantage of being suited to the solid wastes of developing countries.

7.2.3 Vehicle body size

It is necessary to undertake a survey of waste density, per capita generation and population density in any area to be served, together with comparisons of vehicle and labour productivity for different vehicle sizes in order to select the optimum size of waste collection vehicle. In many situations two small vehicles, with their faster and easier loading, are found to be more productive than a single large vehicle carrying twice the load of a small truck. The

30. *Axle loading is the total weight that can be transmitted to the road by all the wheels on one axle.*



Roll-top truck: typical loading height 1.6 – 1.8 m

Fore and aft tipper truck: typical loading height 1.4 m

High-sided open top truck: typical loading height 2.0 – 2.2 m

Rear-loading compactor truck: typical loading height 1.1 – 1.2 m

Figure 7.5 Vehicle loading heights should not exceed the height of the loader's shoulders (1.5 m)

ztwo small trucks may incur similar costs to the large truck although they will require more trips to the disposal site. Table 7.1 illustrates this point in a typical situation by comparing one large vehicle with two smaller vehicles with the same combined capacity. (Both vehicles are assumed to be of the non-compaction high-sided body or "roll-top" body type – see Section 7.6).

It is assumed that the large truck in Table 7.1 has a gross vehicle weight of 10,000 kg (a typical 5 ton capacity truck) and can carry a heaped load of 5,000 kg. To achieve this load with a waste density of 500 kg/m^3 it requires a body capacity of 10 m^3 and has a loading height of around 2.4 metres. The crew of five can collect two loads of wastes per day. The small truck has a gross vehicle weight of 5,000 kg (a typical 2 ½ ton capacity truck) and requires a body capacity of 5.0 m^3 for the same waste density. The crew of three can collect three loads of wastes per day because loading is much quicker with the smaller body and the lower loading height of 1.7 m.

The total cost (capital, fuel, labour and maintenance) for the large truck is approximately twice that of the small truck.

Table 7.1 shows how, very often, two small vehicles can be more cost-effective than one large one. Vehicle productivity in this example for two of the smaller vehicles is 50% more than for the single larger one and the corresponding labour productivity is 25% more for the small vehicles. Using small vehicles also gives more flexibility to the operation and allows narrower streets to be accessed. It is important to remember that this is just an illustration, and should not be used as a universal rule. There are situations where it is better to use one large vehicle. Comparisons should be made between large and small vehicles for each individual situation. Bigger is not always better. Economies of scale do not apply in every situation. (Further examples of calculations are given in Annex A3.)

It is a common mistake when selecting waste collection vehicles to consider only a small range of vehicle types and sizes. The following sections present the wide range of vehicle types that is available and provide practical guidance that can lead to economical and reliable solid waste collection services.

7.3 SMALL WASTE COLLECTION VEHICLES

7.3.1 Handcarts and tricycles

Human powered wheel barrows or handcarts may be appropriate where haul distances are short, typically up to 1 km, and there are no steep slopes. Human-powered vehicles may be the only feasible option in areas of high-density housing where larger vehicles cannot operate or in areas with very congested traffic. Load-carrying tricycles

Table 7.1 Comparison between large and small non-compaction vehicles

Description	Large tipping truck	Small tipping truck
Gross vehicle weight (kg)	10,000	5,000
Weight of chassis and cab (kg)	3,500	1,800
– therefore allowable weight of body and payload (kg)	6,500	3,200
Weight of body (kg)	1,500	700
– therefore payload (kg)	5,000	2,500
Body volume required for waste density 500 kg/m³ (m³)	10.0	5.0
Body dimensions l x b x h (m)	4.0 x 2.2 x 1.14	3.0 x 2.0 x 0.83
Tyre diameter d (m)	1.02	0.74
Clearance between body and tyre c (m)	0.20	0.15
Loading height h + d + c (m)	2.36	1.72
Round trip time (hours)	3	2
Typical engine size (hp [kW])	120 [90]	75 [56]
Number of trips per day	2	3
Vehicle productivity (kg/vehicle/day)	10,000	7,500
Number of workers per vehicle, including driver	5	3
Labour productivity (kg/man/day)	2,000	2,500

have a range of around 2 km since they can be pedalled to the collection area, and, if well designed, even be pedalled when loaded. They can be operated by either men or women, but in some cultures it is not accepted for women to ride tricycles.

The design of handcarts has already been discussed in the context of street sweeping in Section 6.3.3. The following examples, which are related to primary collection more than street sweeping, illustrate some additional points regarding the design, use and maintenance of handcarts and tricycles:

- In Hanoi City in Vietnam, women use handcarts to collect wastes, ringing a bell as they approach so that the householders bring their own wastes out to the handcart. Typically, the handcart travels about 1.5 km during one collection round. The handcarts are well designed and brightly painted with large wheels so that they are easy to push. The collectors wear smart uniforms and so create a good image for the city. (Photo 7.1) (However in many countries poorly designed hand carts result in very arduous work for the operators, low labour efficiencies and a poor image for the city.)

Photo 7.1 Primary collection in Hanoi, Vietnam. Residents are bringing their wastes.

Photo 7.2 Tricycles in Kunming, China – *Load behind driver*

a) load in front of operator blocks view

b) pushing tricycle to transfer station

c) A long line of tricycles waiting to transfer their loads at rendezvous point

Photos 7.3 Primary collection in Ho Chi Minh City, Vietnam

- In Kunming City in China, tricycles with rear-mounted containers, each operated by one man, are used to collect wastes from under the refuse chutes of high-rise apartments, and bring the wastes to a small transfer station at a distance of no more than 1 km (Photo 7.2). In this way, each operator is able to collect 2,200 kg of wastes per day. This demonstrates both the efficiency of the tricycle and the effective use of the small transfer stations. (The use of small transfer stations is described in Section 8.2.4).

- In Ho Chi Minh City in Vietnam, load-carrying tricycles, with the load in the front of the tricycle, are used for collecting the wastes from houses. The wastes are then brought to *rendezvous points* where they are loaded into compactor trucks for transfer to the disposal site. However the tricycles may have to wait at the rendezvous point (Photo 7.3.c) for a long time for the truck to arrive. Therefore, to minimise their working hours, the tricycle operators collect the maximum possible loads each time by extending the sides of the tricycle bodies. Loads of up to 1.5 m^3 have been noted. As a result the load is too heavy for the cyclist to pedal and the load, being in front of the operator, prevents him from seeing where he is going (Photo 7.3.a). The tricycles must therefore be pushed by two men to the rendezvous point. The recent introduction of "small transfer stations" in Ho Chi Minh City should eliminate the waiting at transfer points and greatly improve the efficiency of the tricycle collection. The introduction of tricycles with smaller loads behind the driver and a lower gear ratio should eliminate the need to push the tricycles.

Many of the design considerations mentioned in connection with street sweeping are also important for waste collection. In many cases the capacity of a cart for waste collection must be larger than for street sweeping – a fact powerfully illustrated by the way many waste collectors pile waste as high as they can on their carts before heading for the transfer point. Larger loads mean that the design and condition of the wheels are more important. Three- or four-wheeled carts remove the need for lifting or balancing of the load, and if none of the wheels swivels about a vertical axis, the axles should be positioned so that it is easy for the operator to use his weight to tip the cart slightly so that it can be turned to go in a different direction. In designing the whole collection system, careful attention should be given to developing an economical and hygienic means of transferring the waste from the cart to the next stage of transport. Waste may be transferred by manually lifting and emptying multiple bins, or by using the mechanical bin-lift on a truck, or by tipping the contents into a container at a lower level.

Handcart operators often remove items that they can recycle from the waste that they collect. This is usually not officially allowed, but is common practice in many countries. In some situations it may be worth considering trying to improve this recycling by providing hooks for bags or other means of extra storage for separated recyclables on the cart and perhaps a tray which rests on part of the cart onto which the waste can be tipped for rapid sorting. Collection routes should not be reduced if this sorting and recycling is allowed, and collectors should be allowed to choose to refrain from recycling (and therefore finish their work sooner) or gain a little extra income from recycling, taking more time to complete their daily assignments.

Handcarts and tricycles, together with animal carts (which are discussed next) have the advantage that they do not require that the operator has a driving licence.

a) It is easier to lift the donkey with the cart than to undo the harness. (Unhappy donkey)

b) Redesigned cart & harness allows bigger payload, better weight distribution and easier tipping.

Photos 7.4 Improvements to donkey cart waste collection in Faisalabad, Pakistan

7.3.2 Animal transport

Donkeys, mules, horses and buffaloes are used for pulling loads in many countries, including Pakistan and rural areas of Egypt. Animal carts can be effective in waste collection for distances up to 5 km. Attention must be paid to the design of the carts and the harness to minimize the loads that the animals must support and to simplify tipping. In steeply-sloping communities with unpaved access roads, donkeys and mules can carry waste in panniers (a container on either side).

In Faisalabad in Pakistan, a recent study showed that the existing donkey carts were inefficient, due to their small load capacity and slow emptying. They were also unnecessarily difficult for the donkeys to pull because of the poor balance, and slow to unload because of their inefficient harnesses (Photo 7.4.a). A new type of donkey cart was designed which greatly increased the load capacity whilst reducing the burden on the donkeys and improving the image and status of the waste collectors (Photo 7.4.b).

In Cairo (Egypt) the wastes were traditionally collected by the Zabaleen[31] using donkey carts pulled by up to three donkeys. These carts were very badly designed and were fitted with wheels made from parts of abandoned armoured vehicles. The donkeys were fed with food waste separated from the mixed waste that they collected. These carts were said to cause considerable traffic congestion and were considered to be very unsightly and inappropriate in a city of the size and status of Cairo. Starting in the 1980s, the Zabaleen were instructed to stop using donkey carts, so they replaced them with pickups with high-sided bodies. Occasionally donkey carts are still seen in Cairo, mainly used for collecting segregated cardboard.

Further information about animal-drawn carts can be found publications listed in Annex A6.2.2.

7.3.3 Motorcycle trailers

Small two-wheeled trailers pulled by motorcycles are also used for waste collection. The capacity of the trailers is small, but they are able to negotiate narrow lanes and move quickly even through dense traffic. They are especially suitable for collection from areas of low housing density, because of their speed. Traffic regulations may prohibit their use in some countries. An example is shown in Photo 7.5.

31. *Zabaleen is the name given to a group of people who migrated to Cairo from upper Egypt and who earn their living by collecting and recycling waste from the more prosperous parts of Cairo.*

Photo 7.5 Motorcycle & trailer (Vietnam)

7.3.4 Two-wheeled tractors (power tillers)

Small two-wheeled, pedestrian-controlled tractors (power tillers), typically with single cylinder 6 kW to 12 kW diesel engines, have been adapted for use as waste collection vehicles in countries such as Sri Lanka, Ghana and Kenya (see Figure 7.6). These Chinese manufactured tractors can provide a very low-cost primary collection vehicle for haul distances up to 8 km. Slow speeds (up to 20 km/hr), lack of suspension and limited waste carrying capacity prevent their wider use as waste collection vehicles but they can serve a useful role as primary collection vehicles where there are short haul distances or where they can discharge their wastes into larger vehicles or at transfer stations. The low engine speed gives these vehicles a long, trouble-free life and a very small fuel consumption. In some countries special "type approval" must be obtained before they can be used legally on the roads. A typical power tiller conversion can carry solid waste in eight or ten 100 to 120 litre bins, which are light enough be manually lifted by two men and emptied into containers at the transfer points.

7.3.5 Three-wheeler auto-rickshaw

Three-wheeler auto-rickshaws are manufactured in India and a few other countries where they are widely used as local taxis. Adaptations of this common vehicle for solid waste collection are fitted with either an open or closed body of about 1.0 m^3 capacity (see Figure 7.7). They are in use in many Asian countries and starting to appear in a number of African countries. They have the advantages of narrow width and relatively high speed (up to 30 kph) and, therefore, can operate in congested urban centres within a radius of about 5 km from a transfer station. Earlier versions of this truck were fitted with two-stroke petrol engines which had relatively high fuel consumptions and caused quite a lot of air pollution. Later versions are now available fitted with more economical single-cylinder diesel engines or four-stroke engines which are less polluting.

These vehicles are very suitable for use with small transfer stations and can be tipped either by hand – by two men lifting up the front of the vehicle – or by simple hand-pumped hydraulic tipping cylinders.

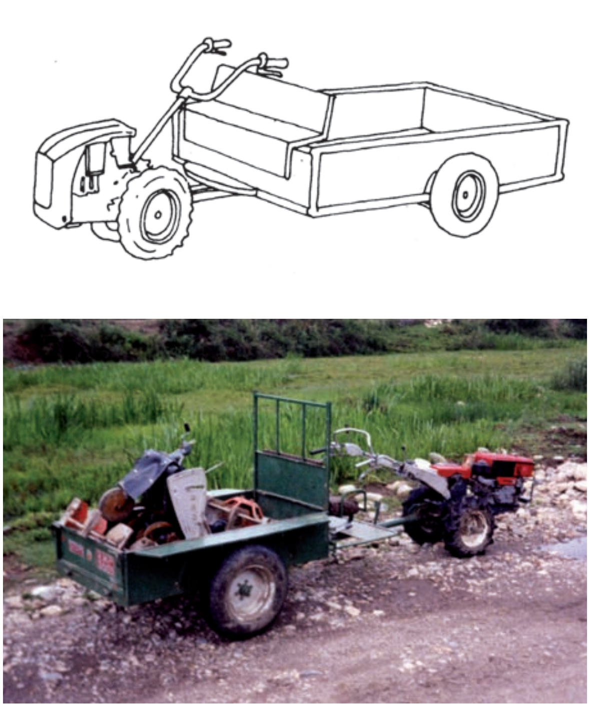


Figure 7.6 and Photo 7.6 Low-cost two-wheel tractor adapted for waste collection

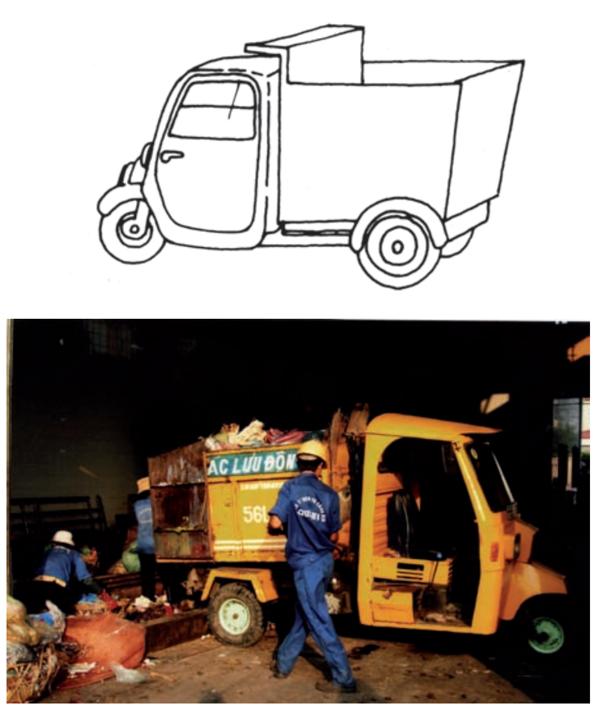
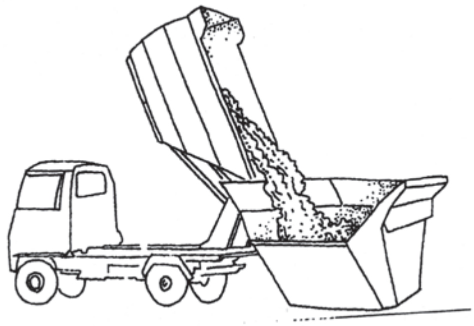


Figure 7.7 and Photo 7.7 Three-wheeler auto-rickshaw

The drawbacks to this type of vehicle are the small wheels (which may not be suitable for very rough roads) and the lack of cab space for the loading crews. They are often operated by a driver with one loader.

7.3.6 Micro-truck with refuse body

Small micro-trucks (Figure 7.8) can be fitted with tipping refuse collection bodies, usually with capacities of up to 1.5 m^3 and open tops or hinged lids. The basic trucks are manufactured in several countries including Japan, China, India and Egypt and are widely available. Conventional and high-tipping bodies can be manufactured locally. Trucks of this type have proved very reliable in a number of Egyptian cities. Conventional tipping bodies are very suitable for use with small transfer stations (Section 8.2.4) and high-tipping bodies enable these trucks to discharge directly into large transfer containers. The small wheel size and low chassis height result in low and convenient loading heights, enabling fast loading, but they are not suitable for very badly potholed roads due to their small ground clearance. With widths of only 1.5 m they can reach into many areas where larger vehicles cannot go and are very good in heavy traffic conditions. At the time of writing these trucks are only available with petrol (gasoline) engines but it is hoped that more economical diesel-engined versions will soon be available.



a) showing convenient loading height

b) discharging load directly into container

Figure 7.8 and Photos 7.8 Micro-truck with high-tipping body

7.4 AGRICULTURAL TRACTORS AND TRAILERS

7.4.1 Tractors

Because of the widespread use and relatively low cost of farm tractors in developing countries, the tractor and conventional open trailer is a common combination. Tractors have longer economic lives than trucks because of their low engine speeds and simple construction. They do not have suspensions (axle springs) and their cabs are simple, with very few sheet metal parts, so they are very resistant to corrosion. It is normal practice to depreciate trucks over seven years and tractors over ten years, so their depreciation costs are greatly reduced (see Section 10.3.1). Tractors have a lower fuel consumption and lower maintenance costs, compared to trucks. Also, it is possible to fully refurbish a tractor at a much lower cost than a truck. For example, only two or three of a tractor's eight gears may be used regularly so that transmission wear is reduced, and the gearboxes themselves are very simple because they do not have synchromesh. It is therefore possible to keep tractors working for much longer periods with only simple repairs.

Tractors are equipped with hydraulic pumps to operate their rear lift arms and external hydraulic connections are available for operating tipping trailers and other equipment.

Agricultural tractors are very commonly used for waste collection in developing countries (and also sometimes in industrialised countries) because of their reliability and relatively low cost. Although their slower road speed (typically 30 kph) is sometimes criticized, they can keep up with slow-moving urban traffic, but they are slower than other traffic on the roads leading to disposal sites. Tractor systems are generally considered appropriate for haul distances of up to 20 km, but have on occasions been used for distances of 40 km and more. Tractors must be fitted with secure seats for any crew and some models offer little comfort for the driver.

The power-to-weight ratio of a loaded tractor and trailer combination determine its fuel consumption, speed and rate of acceleration. A power-to-weight ratio of around 6.0 hp (4.5 kW) per ton of gross weight is enough for a tractor to keep pace with urban traffic and provide sufficient acceleration, but this should be increased where there are steep hills or high altitudes. The manufacturers' horsepower ratings of tractors are determined at an altitude of 150 metres above sea level, and power losses of about 3.5% can be expected for every further 300 metres increase in altitude. In addition, a 2% power loss can be anticipated for every 5.5 C temperature increase above 30 C. In most instances a 45 hp (34 kW) tractor is appropriate for refuse collection, and suitable for a gross weight of 7.5 tons. Typically this would be made up as shown in Table 7.2.

Thus a 45 hp tractor would be adequate for operations at a low altitude on reasonably level terrain but at, for example, an altitude of 1,500 m and an ambient temperature of 40°c and hilly terrain, a tractor of 50 to 55 hp would be more suitable for the loads shown in Table 7.2.

Table 7.2 Typical power-to-weight ratio

Weight of tractor	1,750 kg
Weight of empty trailer	1,500 kg
Maximum weight of waste load	4,250 kg
Gross weight	7,500 kg or 7.5 tons
Power-to-weight ratio for 45 hp tractor	**45/7.5 = 6 hp/ton**

A tractor of this size together with a good trailer normally cost about one half the cost of a tipping truck of the same load capacity. The annual operating and financial costs for the tractor and trailer can be expected to be about 40% of those of the truck. The trailer is faster and more hygienic to load if it has a lower loading height, (which can be arranged by improving the design of the trailer, as discussed in the next section).

There are also smaller four-wheeled tractors which are about one metre wide and can pull trailers of similar width. Vehicles of this kind can be used in narrow alleys, such as in the Old City of Jerusalem.

7.4.2 Trailers

Despite the advantages of low costs, good maintenance prospects and its suitability for use on poorly surfaced roads, the tractor and open trailer combination has in general not been used to its full potential in waste collection because the general purpose trailers that are commonly used have small capacities and lack the manoeuvrability needed in narrow streets with tight corners. For areas with narrow streets the trailer width can be the same as

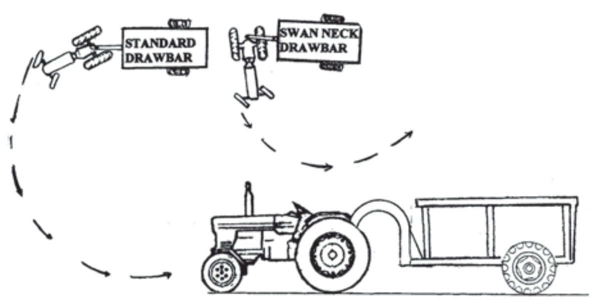


Figure 7.9 Swan neck trailer drawbar greatly improves manoeuvrability

a) This design allows greater capacity and easier loading, and swan neck drawbar allows greater manoeuvrability

b) Body is wider at the top

c) There must be sufficient clearance between the drawbar and the tractor wheels to allow for uneven ground

Photos 7.9 Low loading height trailer with swan neck drawbar

the tractor width (about 1.7 metres) but otherwise the trailer may be 2.0 to 2.2 metres wide.

A conventional tractor trailer as supplied with a 45 hp tractor has a body with internal dimensions 3.0 m long and 2.0 m wide, with sides 0.4 m high, so that the capacity of the body, even when the refuse is heaped up above the sides, is only about 3.0 m^3. The flat-decked body is above the wheels so that, depending on wheel size, the loading height for such general-purpose trailers is about 1.6 metres. If the waste has a density of 500 kg/m^3 the trailer can carry, at most, a load of only 1,500 kg, which is less than one half the tractor's load capacity. (The density of waste just after it is loaded is often lower than the value used here, suggesting that it is not uncommon for the weight in the trailer to be significantly less than this estimate.)

The size of body appropriate for this tractor can be calculated by dividing the maximum waste load by the density of the wastes in that particular situation. For example, if the average waste density is 500 kg/m^3, the 45 hp tractor referred to above should have a maximum trailer capacity (when the load is heaped up) of 8.5 m^3 if operating at sea level and at ambient temperatures below 30 C, or 6 m^3 at the higher altitude and higher ambient temperature referred to in the previous section.

A greatly improved waste trailer with a low loading height can be made if the deck (or floor) of the trailer is lowered so that it is between the trailer wheels, and the sides slope out over the wheels to increase the heaped capacity to 5 m^3 or more (see Photo 7.9).

A further disadvantage of the conventional trailer is that its drawbar is attached between the tractor wheels so that the turning circle is limited by the drawbar hitting the wheels. To improve its manoeuvrability, the trailer can be fitted with a "swan neck" drawbar which allows the tractor wheel to pass under the drawbar during tight turning (see Figure 7.9), but this requires also that a special drawbar attachment is fitted to the tractor.

The trailer axle should be located so as to transfer around 1,000 kg of downwards load onto the tractor drawbar when fully laden, thus reducing the weight on the trailer wheels and adding weight to the tractor's rear wheels for improved performance on soft ground at landfills. The extra weight improves the traction of the rear wheels, reducing slipping, and there is less weight on the front wheels so that they are not forced down into the waste. This modification of the weight distribution makes a conventional tractor just as effective as a four-wheel-drive tractor on soft ground, at a considerably lower cost. With this modified weight distribution a tractor and trailer can travel on soft ground where a truck would "bog down".

Tractors can also pull special container pick-up trailers which can pick up, transport and discharge containers full of wastes, making a very effective waste transfer system. This is further discussed in Sections 5.3.5 and 7.9.1, together with a proposal for a high-tipping version of this type of trailer.

7.5 TRUCK CHASSIS AND CABS

7.5.1 Chassis

Refuse collection trucks can be considered to consist of three parts – chassis, cab and load-carrying body. There is often a choice of cabs available for any particular chassis. The body is usually mounted on the chassis by the manufacturer of the body, but most bodies can be fitted onto chassis of many different makes, so it is important to specify the chassis/cab and body separately, though, of course, they must be compatible. This section discusses the selection of chassis and the following sections review the many different types of body which can be fitted onto truck chassis.

Trucks can be divided into three main categories.

- Micro trucks with load capacities of up to 1 ton and typical widths around 1.8 m (see Section 7.3.6).
- Small (or light) trucks with load capacities of up to 4 tons and widths of 2.0 m. These trucks commonly have 16 inch tyre sizes giving a low chassis height and a corresponding low loading height.
- Large trucks with load capacities of 7 tons to 12 tons with 20 inch tyre sizes. The chassis heights vary from manufacturer to manufacturer, with a consequent effect on the loading height of any body that is fitted, but inevitably these trucks have high loading heights.

When selecting a vehicle chassis for refuse collection, the first step is to decide on the category of truck required, (micro, small or large) and then to study the range of truck chassis that are available in the country concerned. The first essential must be to choose a truck with good spare parts and service, irrespective of its country of origin. A quick survey of all the trucks operating in the area concerned will narrow the choice down to a small number of different makes that are popular. Discussions with truck operators will reveal which ones have a good performance and service history in that country. A visit to the importer or dealer of the chassis that are most likely to be chosen will indicate what stocks of spare parts are kept, which particular model of that make of chassis is preferred, and what chassis lengths (wheelbases) and engine and transmission specifications are available. Manual gearboxes are often preferred because they are easier to maintain, but unskilled drivers can very quickly wear out the clutch plate of a truck that makes many stops on its collection route. Because of this problem with clutches, and to simplify the task of driving, automatic transmissions may be specified where good maintenance of that type of transmission is assured.

In general larger trucks are fitted with diesel engines and smaller ones are available with a choice of petrol or diesel engine. Diesel engines are more economical and generally last longer than petrol engines.

There are many different sizes and types of truck chassis which can be adapted for waste collection, with different widths, load capacities, wheel sizes, chassis heights, engine sizes, wheelbases (distances between the front and rear axles), transmissions (automatic or manual), suspensions and braking systems. Some chassis may be more suited to fast travel on good roads, and others to more arduous conditions – bad roads, steep hills, dusty environments etc.

Chassis may have one or two rear axles and single or twin wheels on each axle. A chassis with a single rear axle is commonly designated a 4 x 2 truck (4 wheels, two of which are driven by the motor. No differentiation is made between single and double wheels). A truck with a double rear axle is commonly designated a 6 x 4 truck if all rear wheels are driven. 4 x 4, 6 x 6 and 8 x 4 trucks are not commonly used for waste collection. When a truck with two rear axles turns sharply, the rear wheels are subject to sideways forces which are transmitted to the road surface as they roll forwards or back. This “scrubbing” motion increases the rate of wear of the tyres and damages the road surface. One method of reducing the effects of this problem is to raise one of the axles off the road when the vehicle is not fully loaded. Chassis of this kind will be unsuitable for driving on disposal sites as the axle that can be raised is not driven by the engine. (See Annex A4.4.6 for further comments on driving on disposal sites.)

When selecting a chassis for waste collection, the most important aspect of all is to ensure that there is a local service capability and a comprehensive supply of spare parts for the basic truck chassis and cab and that wherever possible the truck bodies are manufactured locally so as to ensure that spare body parts are readily available. (This has been discussed in Section 7.1.8.)

7.5.2 Cabs

Apart from the location of the driver’s seat (left-hand or right-hand drive), an important aspect of the specification of the cab is the crew accommodation. The size of the crew is determined by many factors including method of loading, loading height, wage levels and agreements with labour unions. Riding on the waste is not acceptable for reasons of health and safety. Rear platforms for the crew are common in most countries but should only be used for short distances. Single cabs can generally accommodate only two loaders, so double cabs (having two rows of seats) should be specified if more labourers (and perhaps a foreman) must ride with the truck, unless satisfactory crew accommodation is provided on the body behind the cab.

Vehicles that discharge their loads at transfer stations or treatment plants may be driving always on uniform, paved roads. For such duties, trucks may be fitted with low-entry cabs that allow the crew to enter and leave the cab quickly and conveniently. Such cabs are not suited for vehicles that drive on soft and uneven surfaces at disposal sites because the bottom, front edge of the cab will hit the deposited waste, be damaged and prevent the vehicle from moving forwards. Furthermore such cabs add considerably to the cost and must be imported specially, with the consequent problem of obtaining spare parts.

Air conditioning may be specified in hot climates, particularly because open windows at most disposal sites in the developing world attract large numbers of flies.

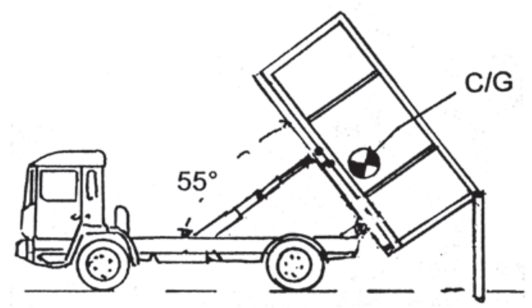
7.6 NON-COMPACTING COLLECTION VEHICLE BODIES

The following sections describe some of the many alternative body types for motorised vehicles that do *not* reduce the volume of the waste they carry by compacting it hydraulically.

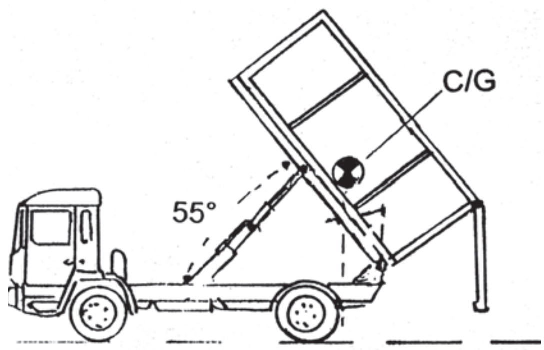
In most developing countries the wastes are sufficiently dense that the full payload of the refuse truck can be reached without compacting the wastes. In these circumstances, there is little need to use expensive, complex and heavy compactor vehicles. Even so, some judgement is required in selecting the most appropriate type of non-compaction body, in order to optimise vehicle utilisation and productivity. The nature and design of the body has a significant effect on the speed of waste loading and, hence, on the amount of waste which can be collected daily. Non-compaction vehicle bodies require a larger load space than a compactor body to enable the vehicle to achieve its payload. The bodies are however, lighter and, therefore, permit greater payloads than compactors in all cases where the density is high enough so that an economic load can be carried on the truck. Non-compaction bodies invariably have lower capital, operating and maintenance costs than compaction bodies (which have costly mechanisms in direct contact with abrasive and corrosive wastes). This is further explained in Figure 7.21 and Table 7.3, in Section 7.8.1.

Attention to small design details is critical for any refuse body. Most non-compacting bodies are emptied by tipping. Figure 7.10 illustrates how the location of the hinge point on a tipping body can make the difference between an efficient waste collection vehicle and an inefficient one which will not return to the lowered position and will suffer damage as soon as it is put into operation. Figure 7.10.a shows a badly designed tipping truck body. Figure 7.10.b shows a well designed one.

Conventional low-sided tipping trucks generally have tipping angles of 48° and the hinge point of the body is around 40cm forward of the back of the body. However waste collection vehicles must have tipping angles of at least 55°, otherwise the waste will not slide out of the tipped body because of the friction between the body and



a) Conventional hinge position for tipping truck: body will not return by gravity and tailgate touches ground



b) Improved hinge position: body returns by gravity and good clearance under tailgate

Figure 7.10 The location of the point at which the body is hinged to the chassis is an example of a design detail that can have a major impact on the operation of a vehicle

the wastes. If the sides of a conventional tipping truck are raised there may be a number of problems including:

- If the required 55° tipping angle is used, the centre of gravity (C/G) of the body will pass behind the hinge point, particularly when facing uphill. This means that the body will not return by gravity after tipping. This can be overcome by fitting a special tipping ram with a double action first stage, but this is costly and requires a special valve and additional hydraulic hoses to operate it. Figure 7.10.b illustrates how by simply moving the hinge point rearwards the C/G of the tipped body is now forward of the hinge point so that the body will return by gravity.
- If the hinge is located too far forward, the tailgate will touch the ground when the body is tipped. This means that the tailgate will quickly become damaged and unable to close.

This example shows how a very small design change can have a very significant impact on the efficiency and effectiveness of a waste collection vehicle.

7.6.1 High-sided open-top vehicles

High-sided open-top vehicles are conventional tipping trucks with the sides extended upwards to increase their capacity. Examples of this type of vehicle are shown in Figure 7.11 and in Photo 7.10.

These are extremely slow and unhygienic to load, as the wastes must be passed up from ground level to a worker inside the truck who packs the load or, alternatively, the wastes must be thrown up into the body by means of forks or shovels. Both loading operations are unhygienic, especially since they entail raising wastes above the loaders' heads, resulting in wastes falling back onto the loaders' heads and the surrounding area. Although this type of vehicle is used extensively in developing countries, where they are readily available and often locally assembled, they are, perhaps, the least cost-effective of all non-compaction vehicles. High-sided bodies fitted to larger truck chassis have loading heights which are often in excess of 2.5 m (see Photo 7.10). Smaller trucks are easier and faster to load, although they still have excessive loading heights. The slow loading speed caused by the high loading heights results in excessive numbers of these vehicles being required. There is also a tendency for litter and loose wastes to blow off the top of the truck while travelling, unless loaders are instructed to secure a net or tarpaulin over the load, and this instruction is rigorously enforced.

If the load is piled above the sides of an open body

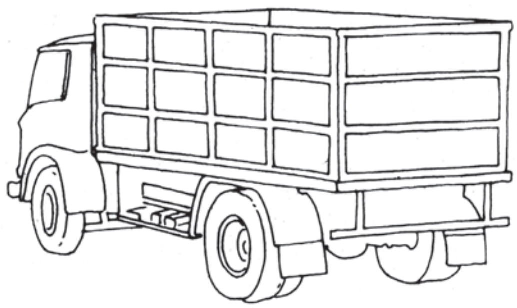


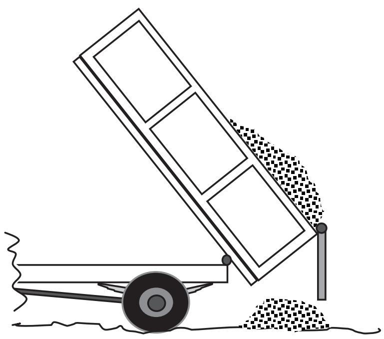
Figure 7.11 High-sided open top vehicle

Photo 7.10 High-sided vehicle with side doors to assist loading

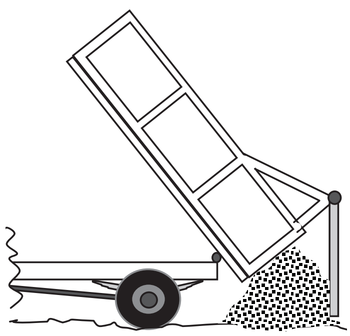
truck, and remains above them at the end of the journey, even after vibration has reduced the volume of the load, there may be problems in unloading the vehicle when the mass of cohesive waste hits the top of the tailgate, as shown in Figure 7.12.a. This problem may be avoided by raising the top of the tailgate as shown in Figure 7.12 (b and c). An alternative approach is to use two rear doors which are hinged at the sides of the body (Figure 7.12.d), provided that they are securely fastened to the sides of the body before tipping. (If they are not securely fastened they will swing back when the body is tipped, causing serious injury to anyone standing near them and perhaps becoming damaged if they reach the ground and are forced down by the tipping mechanism.)

These considerations may also be relevant to other types of non-compacting collection vehicle.

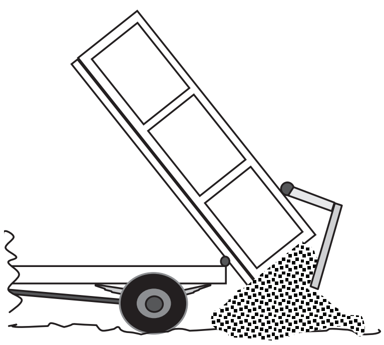
Contracts that include the provision of trucks for collection services and that are for too short a period often result in contractors using very old vehicles that do not tip to unload, (known as *rigid* or *fixed body* trucks). They use these vehicles because they are cheap to buy and can be used for other purposes if their waste collection contracts are not renewed. Such vehicles may have a lower loading height than those with tipping bodies, but the extra time taken to unload them manually and the additional



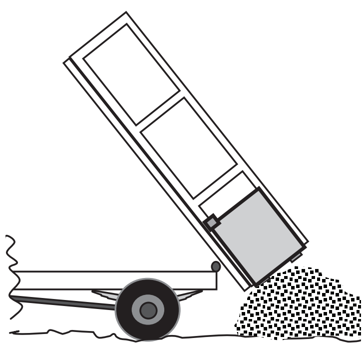
a) The top of the tailgate may prevent piled up waste from sliding out of the body



b) Raising the top of the tailgate allows the waste to slide out freely



c) The tailgate is linked to the hinge by arms at either side and so is raised above the waste



d) Doors which open sideways must be securely fastened before tipping starts

Figure 7.12 Design options for the rear of open tipper truck bodies

health risks for the labourers make these vehicles even less acceptable than open tipping trucks (Photo 7.11).

Photo 7.11 Manual unloading of rigid truck at disposal site

7.6.2 Side loading "roll-top" vehicles

These vehicles generally have tops shaped like half of a cylinder on the bodies and can be loaded from each side through curved sliding doors, and they tip to empty (see Figure 7.13 and Photo 7.12). This type of vehicle is, perhaps, the most common form of specialised waste collection vehicle found in developing countries. However they are often fitted to short wheelbase truck chassis that are designed to handle heavy materials, such as sand, construction materials and debris, and so the bodies are short and have a small capacity. These vehicles rarely carry reasonable loads of waste. Very often the truck chassis used are designed to carry payloads of 5 tons or more, but the vehicles rarely attain actual payloads of more than 2 tons.

Loading heights are determined by the size of the truck's wheels and the height of the sides. On large trucks, with high bodies, the loaders are not able to reach into the centre of the body and load it fully, and therefore, the vehicle body should be built on a small chassis with small wheel diameters and reduced body widths. In most developing countries, the principal advantages are low capital cost and easy local manufacture.

The productivity of this type of collection vehicle depends on the nature and type of waste storage adopted. Where small standardised bins, readily lifted by collection loaders, are used, vehicle productivity can be maximised. However, where excessively heavy storage containers, such as 200 litre oil drums, are used, as many as five labourers might be required to load the wastes, and at least one of these would need to be inside the vehicle throughout the loading operation. This practice is unhygienic and dangerous and cannot be justified, even if there is an increase in vehicle productivity. Vehicle productivity is drastically reduced when waste storage facilities require the waste to be dumped on the ground prior to being loaded into the vehicle using baskets or forks. The productivity of these vehicles is highest when wastes are stored in bins of typically no more than 80 litres capacity to facilitate loading.

As these vehicles become older, their shutters often become damaged or corroded so that they cannot be closed, As a result, light items of waste may be blown out of them when they travel to the disposal site.

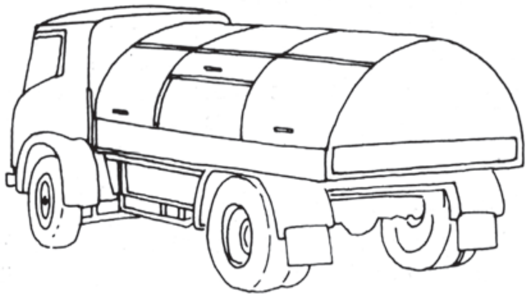


Figure 7.13 and Photo 7.12 Roll-top collection vehicle (side loader)

7.6.3 Front-loading high-sided enclosed vehicles

These vehicles, known as "tipacks", are quite common in some southern African countries. They have a step up to a platform behind the driver's cab, with an opening in the front of the body through which waste is loaded (see Figure 7.14 and Photo 7.13). Waste is passed up to a worker on the platform who fills the front of the body, and, when the front section is full, the body is tipped back with the rear doors closed so that the waste slides to the rear. The body is then lowered and the operation repeated until the vehicle is full. The body is emptied by opening the rear doors and tipping. These bodies can have large capacities but they are slow to load, as there is room to accommodate only one worker on the platform and the loading speed is dependent on this one man. Large storage containers

Figure 7.14 and Photo 7.13 Tipack system – simple, low cost but slow to load

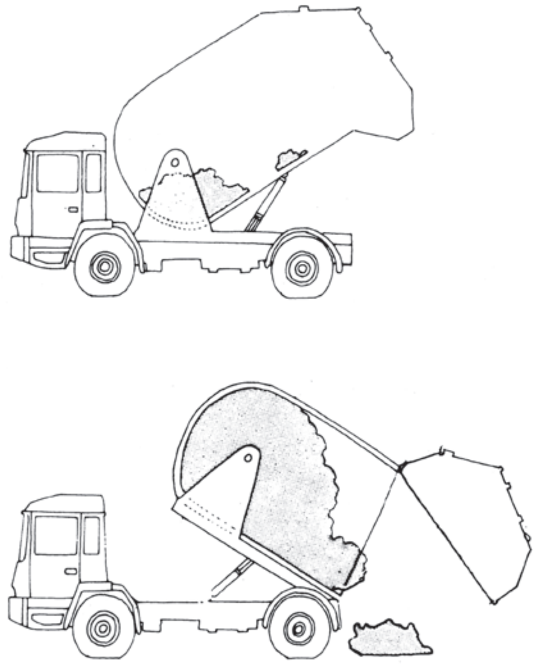


Figure 7.15 Fore and aft tipper – efficient for high-density waste

cannot be used, since the weight of the full containers must not be too much for one man to handle and the space where this loader works is restricted. However, the vehicle productivity is considerably higher than that of the high-sided open truck. The body is easily produced locally in developing countries and has the advantage of being enclosed, thereby preventing light wastes from being blown out of the body when the vehicle is moving.

7.6.4 Fore-and-aft tipping bodies

This type of body was common in Europe during the 1950s and 1960s (when coal was widely used for heating and cooking) when waste characteristics were relatively similar to what they are today in most developing countries. This design of body combines easy, low, rear loading with a relatively high body (providing a large capacity), and there are many situations in developing countries where this system offers several advantages. In Yemen, for example, fore-and-aft tipping bodies, which were many years old, were refurbished and fitted to new truck chassis because of the efficiency of this type of body. It could be manufactured in a majority of developing countries with no more facilities than simple machinery to cut, weld and bend steel sheets, and it can be fitted to any locally available truck chassis. However, the authors do not know of any factory that is currently making this type of body. It presents little or no maintenance problems, and body capacities of up to 12 m^3 are possible with this arrangement. The waste is loaded into the rear hopper. The body operates by tipping in two directions – towards the front for transferring the wastes to the front of the body, thereby creating space for further loading, and towards the rear for unloading (see Figure 7.15). An internal barrier plate pivoted from the roof of the body is sometimes provided to prevent the wastes from falling back as the body is lowered. A small amount of volume reduction, equivalent to a compaction ratio of about 1.2 to 1, results from consolidation under self-weight. Although the fore-and-aft tipping vehicle has rarely been used in developing countries, it is perhaps one of the most suitable and cost-effective of all vehicles for handling the type and nature of wastes that are generated in developing countries today. It is therefore recommended that further consideration should be given to this system. In general, this type of vehicle is suitable for handling wastes with densities above 250 kg/m^3.

7.6.5 Side loading binlift system

This system is commonly used in China with standardised bins of around 100 litres capacity. The bins are wheeled to the side of the vehicle where the lift mechanism picks them up and discharges their contents through the roof

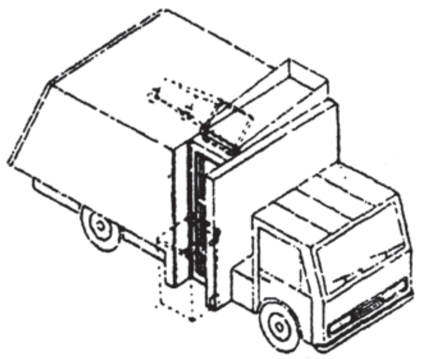


Figure 7.16 and Photo 7.14 Non-compaction truck with binlift

Photo 7.15 Crane tipper truck loading waste

into the front of the body. When the front is full, the body is tipped with the rear door closed so that the wastes slide to the rear, and loading can continue. This is a simple and effective system in which small wheeled bins are used. See Figure 7.16 and Photo 7.14.

Providing standardised bins for primary storage of all the solid waste in the collection area can be very expensive, as illustrated in Annex A3. To reduce this expenditure it would be possible to use just a small number of bins that are compatible with the binlift. The loaders could each be given one of these bins so that they can fill it with plastic bags of waste or transfer waste from individual household bins, and when it is full it can be taken to the truck and the contents tipped into it using the binlift. The loaders' work would be made easier if the bins that they use are fitted with wheels, like the "wheelie" bin shown in Figure 5.3 (Section 5.3.4). When the vehicle is travelling to or from the collection area the bins could be hung on the back of the truck or carried on a small trailer.

7.6.6 Crane-tipper system

This system was developed in Gaza (Palestinian Territories) as an improvement on an original local design which uses a hydraulic crane to reach out from the truck to pick up and empty containers (Figure 7.17 and Photo 7.15). The crane can lift 1.0 m^3 containers at distances of up to 8 m from the truck, so that the containers can be located at some distance from the road on sandy or uneven ground and without blocking footpaths. The crane is fitted with a special attachment which enables the operator to rotate the containers to tip their loads into the open-top body. Because the body can be higher than for trucks that are loaded manually, it is possible to reach the full permitted payload with relatively dense wastes. Loading is quick and hygienic, and unloading is by tipping. Hydraulically operated flaps cover the body when travelling to prevent the wastes being blown out by the wind. This system is

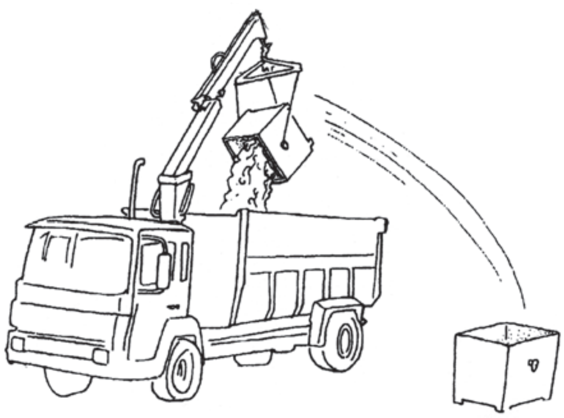


Figure 7.17 Crane system reaches out to pick up containers

efficient and can be operated by one person (though normally the driver has an assistant). It can be used safely if containers are not located under overhead cables (since the crane arm extends relatively high above the truck)[32]. The truck body can be manufactured in most developing countries but the hydraulic crane is a specialised item which must be imported. It is quite costly and requires a good spare parts backup so it is essential that the crane chosen must be a model which is readily available in the country concerned. (In the ten years that these vehicles have been operating in Gaza, the cranes did not pose any maintenance problems apart from the replacement of flexible hydraulic hoses.) A container with a capacity of 1.5 m^3 can be fitted to the rear of the truck and filled from household bins left at the kerbside. When it is full it can be emptied in the same way as the other containers. This system has also been used in conjunction with small tractors fitted with rear-mounted lifting frames which bring full containers to the roadside for emptying by these trucks (Section 7.9.1).

7.7 SEMI-COMPACTION VEHICLES

Semi-compaction vehicles represent a halfway stage between non-compaction and compaction systems. Some reduction in waste volume is achieved which, although it is less than for compaction vehicles, is more appropriate for developing country wastes which vary from medium to high density. The machinery required to achieve the additional compaction is simpler and less demanding in maintenance than complex hydraulic compaction machinery. Some semi-compaction vehicles are discussed below:

32. *In more than 10 years of operation in Gaza there was not a single accident with overhead cables, but this system should be used only by experienced operators who have been thoroughly trained.*

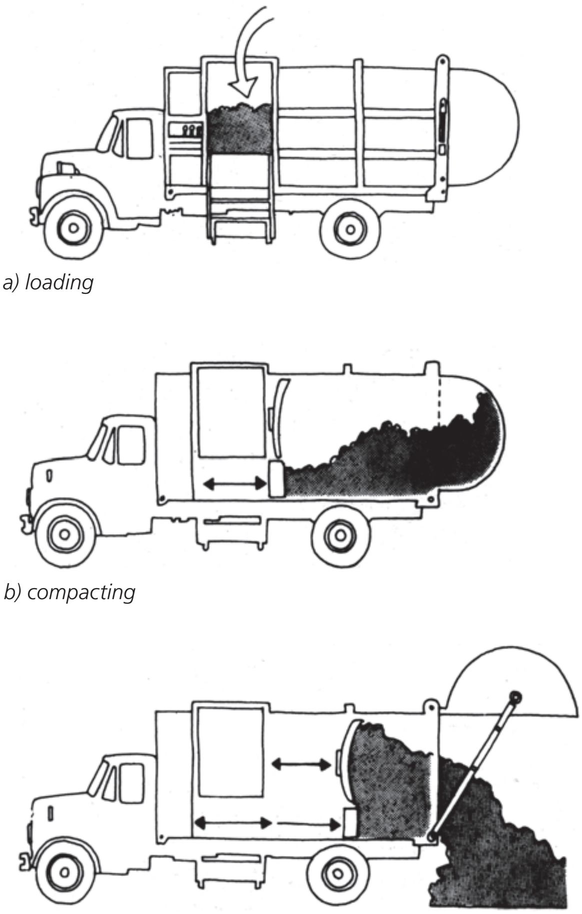
Loading using oil drums presents many risks

Photo 7.16 Side-loading, moving barrier semi-compaction vehicle

7.7.1 Side-loading, moving-barrier, semi-compaction vehicles

These vehicles have openings for loading at each side of the body (Figure 7.18). These openings are high up near the front. A packing plate pushes the loaded waste towards the rear of the body. This type of vehicle has the advantage of a relatively low loading height. However, its small loading doors (see Photo 7.16), reduce the speed of waste loading and the loaders must wait while the machine pushes the waste to the back. The loading aperture can only accommodate one loader at a time and it is common to see an additional worker inside the body to speed up the loading operations by clearing the wastes away from the loading door. This practice, besides being unhygienic, is also dangerous, because the hydraulic mechanism could be operated accidentally, causing the operator to be crushed. Some vehicles of this type have binlift mechanisms which lift and empty wheeled bins into the body. The sliding compaction plate and multi-stage hydraulic cylinders[33], which are fitted within the

33. *See "hydraulic cylinders" in the List of Terminology, Annex A7*



a) loading

b) compacting

c) discharging

Figure 7.18 Operation of side-loading, moving barrier semi-compaction vehicle

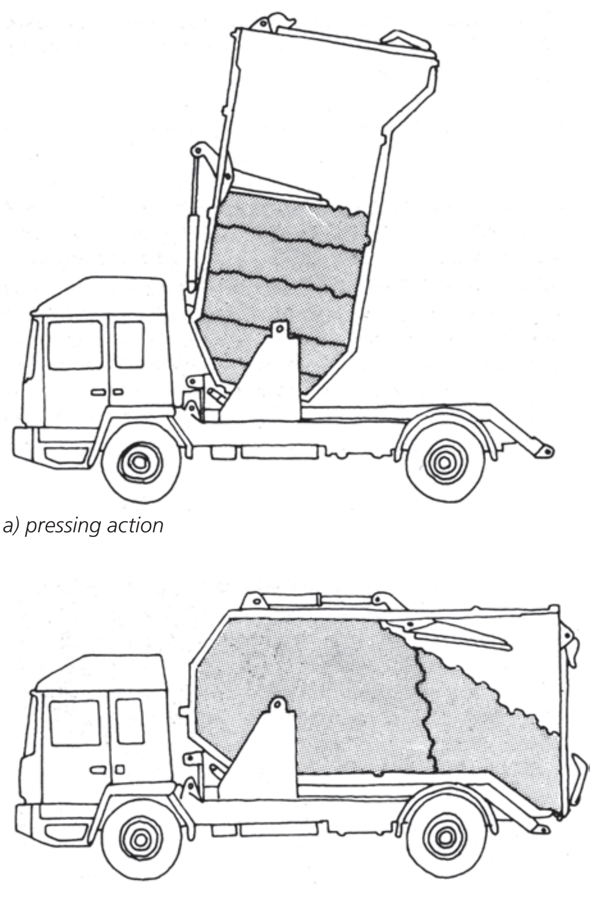
body of the vehicle, suffer from wear, especially if the wastes are abrasive. In view of these disadvantages, the little extra capacity provided by this type of semi-compaction vehicle body, when compared with non-compaction vehicles, is difficult to justify.

7.7.2 Fore-and-aft semi-compaction vehicles

This type of vehicle is a variation of the simple fore-and-aft tipping vehicle already described (Section 7.6.4) and includes a top hinged packer plate operated hydraulically. The plate swings down from the roof of the vehicle and compacts the load towards the front of the body (see Figure 7.19). This is a very simple semi-compaction body, with no sliding parts located within it. The single additional hydraulic cylinder which is operated by a simple manual valve to partially compact the waste is located on the roof of the vehicle and therefore protected from contact with the wastes. This system is ideal for medium-density wastes and can be usefully applied where a proportion of the wastes is contained either in plastic bags or cardboard boxes. The compacting force of the packing plate is usually sufficient to press the air out of most of the bags and squash down large cardboard boxes or other occasional bulky items, which take up a large amount of space. Like the non-compaction fore-and-aft tipping vehicle, this semi-compaction vehicle has considerable potential for use in developing countries, especially in affluent urban areas, but the authors do not know of any case where this type has been used in developing countries.

7.7.3 Side-loading-hopper semi-compaction vehicles

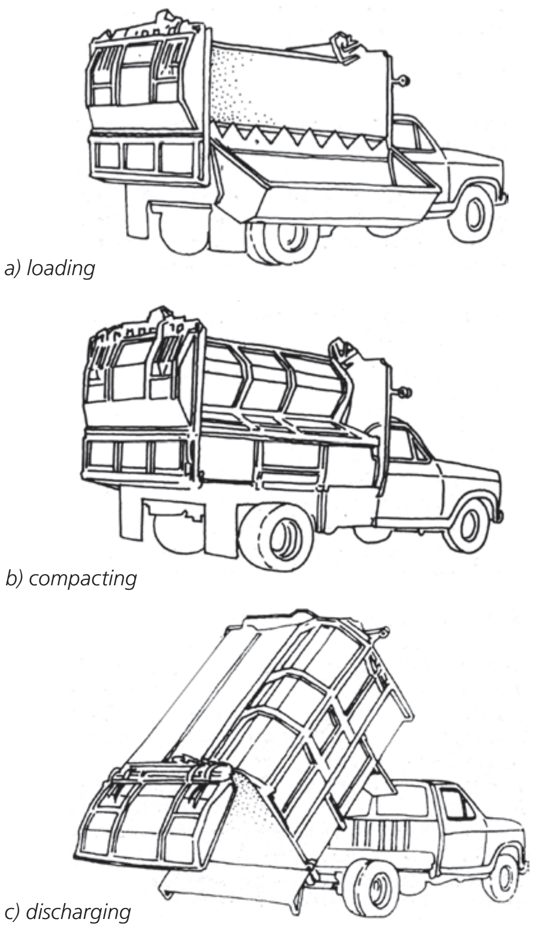
The side loading semi-compaction vehicle was developed in Canada. One side of the body drops down to form a large hopper which is raised hydraulically to tip the load into the body and compress the waste against the opposite side (see Figure 7.20). When the body is full, the collected waste is tipped through the rear of the body. This form of semi-compactor vehicle has the disadvantage of requiring wide streets to operate and is only suitable for loading from one side of the vehicle. It has a relatively slow loading



a) pressing action

b) loading action

Figure 7.19 A variation of the fore and aft body (Figure 7.15), with press plate for some compaction



a) loading

b) compacting

c) discharging

Figure 7.20 Side-loading hopper semi-compaction vehicle

cycle. Therefore, although still used in some industrialised countries, the side loading semi-compaction vehicle has limited application in developing countries; especially where access is limited. Once again this form of semi-compaction vehicle is suitable for medium-density wastes.

7.8 COMPACTION VEHICLES

7.8.1 Introduction to compaction vehicles

Household and commercial wastes in the wealthier and more industrialised countries have very low densities, typically between 100 kg/m^3 and 150 kg/m^3. As a result, compaction mechanisms in the collection vehicles are commonly used to compact the wastes so that an economic load can be carried on the truck within the limits of the truck body dimensions. Usually, after compaction the waste densities are increased to 400 or even 500 kg/m^3 so that the volume reduction (waste compaction) ratio is 4:1 or even 5:1. In developing countries however, it is common to find waste densities at the point of collection in the range 250 to 400 kg/m^3, or even more, and so there is much less benefit from compaction, since any significant compaction of the waste would result in overloading. Developing country wastes contain abrasive sand and ash which cause severe wear on compaction mechanisms. Despite this, consultants from the industrialised countries frequently recommend compactor trucks with which they are familiar in their own countries without any proper consideration of the economics and sustainability of what they are proposing, and salesman from the vehicle manufacturers promote their products as “the modern” method of waste collection without any consideration as to whether they are appropriate. It is very rare for unit costs (the cost of collecting one ton of waste) to be calculated and used as a basis for the selection of the most economical system, in a way similar to the procedure illustrated in Annex A3.

The officials and engineers responsible for waste management in developing countries must be on their guard to avoid being persuaded into using unsustainable compaction vehicles where there are high density wastes. They must resist strongly any attempts to persuade them to introduce collection systems that were designed for countries where there are totally different waste characteristics and different economic and road conditions, without carefully reviewing the implications of all local factors and conditions. Any report which recommends a waste collection system without having first ascertained the density of the wastes to be collected should be disregarded as meaningless.

Before going into more details, the arguments for and against the use of compactor trucks will be summarised.

a) The benefits of using compactor trucks in developing countries are generally as follows:
   - Compactor trucks are able to carry economic payloads in situations where the wastes have a density which is too low to enable a full load to be carried in a non-compaction truck. In some cities there may be low-density wastes in commercial areas where compactor trucks may be appropriate while non-compaction vehicles are more suitable for residential areas.
   - They are readily available. Compactor trucks are produced in large numbers for local applications in industrialised countries, so these vehicles can be supplied with a relatively short delivery time, and the manufacturers are eager to sell as many as possible.
   - They have a sophisticated and modern appearance, pleasing to mayors and other city officials.
   - The waste is largely enclosed. Some liquids resulting from compaction may escape and trucks that have not been washed often emit a very unpleasant smell, but little waste escapes when the truck is moving.
   - Loading is fast and convenient. Most types of compactor have low loading heights so that they are convenient for manual loading, and the compaction mechanism of most models lifts the waste as well as compacting it in order to fill the load-carrying part of the body. Compactor trucks can be supplied with binlift attachments for emptying various sizes of wheeled bins. Large compactor trucks can even empty skips.

b) The disadvantages of using compactor trucks in developing countries are mainly the following:
   - The compacting load-carrying bodies are expensive and not suited to manufacture on a small scale in small workshops, so that they must be imported at considerable cost.
   - The operating mechanisms have many rotating and sliding parts and many hydraulic components. Some models have sophisticated control systems. Mechanics may need special training to keep them in good working order, and trained mechanics must be available throughout the life of the vehicles – as trained mechanics resign for more prestigious work, others must be trained to take over from them. Maintenance is expensive because spare parts must often be purchased from overseas. The wear on sliding parts is accelerated by abrasive and acidic material in the wastes. Not only is the maintenance more expensive for

these reasons, but also the vehicles are out of service for a larger percentage of the time because the complexity of the compaction system causes a higher frequency of failures when compared to non-compaction vehicles. The chassis of compactor trucks can be expected to suffer more breakdowns because they are more likely to be overloaded and the hydraulic systems are used more intensively. Higher downtime (or lower availability) means that the collection service becomes less reliable, unless more vehicles are purchased and operated to maintain the reliability of the service.

- Because of these maintenance difficulties, the working life of compactor trucks is generally significantly shorter than for other kinds of truck.
- The rear loading hopper and compaction mechanisms of some types of compactor truck are so heavy that the load on the back axle is frequently above the legal limit at some stages of the loading process. This overloading can cause road damage (both to the surface and to pipes below the surface) and the uneven weight distribution may result in difficulties in controlling the vehicle.
- Operation of the compaction mechanism may be very noisy, causing complaints from residents if waste is collected at night.
- Fuel consumption of compactor trucks is more than for other kinds because of the higher empty weight and the energy consumed in regular operation of the compaction mechanism.

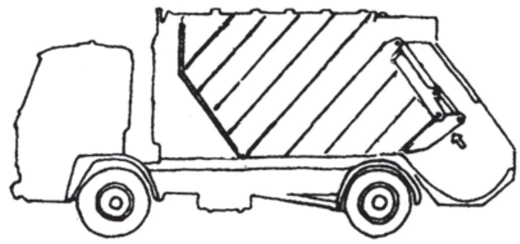
When comparing compactor trucks with non-compaction trucks, it must be understood that there are many types of non-compacting truck which are grossly inefficient because of their inconvenient loading procedure or their small capacity. There is a great need to improve the quality of consultancy advice, particularly in that decisions should be heavily influenced by comparisons of unit costs which are based on reliable, local data. (Examples are provided in Annex A3).

Private sector operators who provide waste collection services often use compactor trucks if the duration of their contract is long enough for them to finance vehicles specifically for the particular contract. Private operators generally have fewer difficulties with maintenance because they are able to adjust their ordering systems for spare parts so that the downtime for any repair is as short as possible. The time allowed to mobilise for a particular contract does not allow them to develop special vehicles but obliges them to order vehicles that can be supplied quickly. It appears that many private operators do not compute unit costs in order to select the most efficient system, even though they are generally more concerned with economy and reliability than public sector operators.

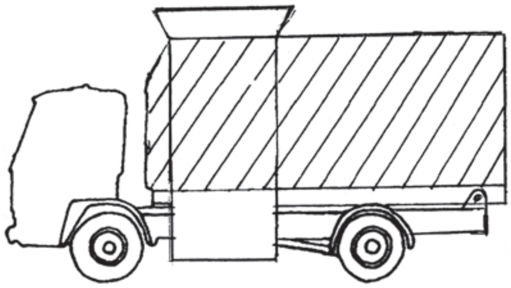
The following paragraphs compare a compactor truck with a non-compacting truck that has an economic payload, without specifying how the latter truck is loaded. Options for loading of such trucks have been described in the preceding sections and will be reviewed briefly later in this section.

Figure 7.21 presents outline drawings of a rear-loading compactor truck (of the type that will be described in the next Section) and a non-compaction tipping truck on the same truck chassis. It shows that not all of the body envelope of the compactor truck is filled with solid waste when the truck is fully loaded. There is empty space in front of the ejector plate and the compaction mechanism occupies considerable space. A non-compacting body, in comparison, can carry waste over the complete length of the body, so that it can devote a significantly larger volume to the waste than the compactor. Furthermore the reduced weight of the non-compaction body allows a greater weight of waste to be carried.

Table 7.3 shows an example based on Figure 7.21 for a typical developing country situation. It demonstrates that, in the particular situation, the non-compaction truck can carry almost 20% more than the compactor truck. It is also relevant to note that the non-compaction truck would incur lower maintenance and depreciation costs.



a) The shaded area indicates storage volume in a rear-loading compactor



b) For the same chassis, the volume of a non-compaction body is significantly more.

Figure 7.21 Comparison of volumes of waste in compactor trucks and non-compaction trucks

It is normal in developing countries for single rear axle (4 x 2) trucks as illustrated in Figure 7.21 to be restricted to a gross vehicle weight (GVW) of 15,000 kg. (In some countries this is reduced to 13,000 kg.). It can be seen from Table 7.3 that the compactor truck exceeds the permitted GVW by almost 12% whereas the non-compaction truck is operating at less than 4% above the legal weight limit.

It has already been explained that the density of the waste is one of the main factors that determines the suitability of compactor trucks. Table 7.4 illustrates this by considering three waste densities, to demonstrate how compactor trucks only become effective when the density of the waste is low and maximum permissible payloads cannot be achieved with a normal size of body fitted to a conventional truck. A compaction body which can achieve a volume reduction of 4:1 or 5:1 with low-density wastes may achieve a volume reduction of only 1.5:1 on high-density wastes. In this example, the overall dimensions of the non-compaction body to achieve the same load are constrained to be no more than that for the compactor truck, so that the volumetric capacity of the open truck is 20 m^3.

For practical reasons the vehicle body capacity of the non-compaction truck is limited to 20 m^3.

Table 7.3 Comparisons of capacities of compactor and non-compactor trucks

Item	a) Compactor truck	b) Non-compactor
Waste density at household (kg/m^3)	350	350
Waste density in truck (from Figure 7.3, kg/m^3)	730	480
Volume occupied by waste (Figure 7.21, m^3)	9.9	17.8
Payload (kg)	730 x 9.9 = 7,200	480 x 17.8 = 8,500
Weight of truck unloaded (tare, kg)	9,500	7,000
Total weight of loaded vehicle (kg)	16,700	15,500

The carrying capacity of the compactor in each case is limited by weight not volume

In this example, which considers a typical rear-loading compactor truck, the body of the vehicle weighs about 3,500 kg, most of this weight being concentrated in the heavy machinery at the back of the truck. The chassis weighs 4,500 kg. Assuming that it is possible to obtain a suitable, balanced load distribution between front and rear axles, and a maximum GVW of 13,000 kg, the maximum permissible payload of waste with a compactor body is 5,000 kg. In comparison, a simple open truck body, with a weight of only 1,500 kg, would allow the same chassis to carry 7,000 kg i.e. 40% more waste. A compactor truck might cost two to three times more than a simple non-compaction truck with greater capacity, and have lower maintenance, running and depreciation costs. The overall cost per ton of payload capacity might, therefore, be three or more times greater for a compactor truck than for an open-body truck, provided that there is an efficient way to load the open truck. Table 7.4 illustrates how increased body weight in vehicles, such as compactor trucks, limits the payload. If compactor trucks that are designed for low-density wastes are loaded with waste of a much higher density, they may become seriously overloaded, causing damage to the axles, springs and wheels of the vehicle, and the roads and the water services under them.

If waste densities are more than 250 kg/m^3 the compaction of solid waste can very seldom be justified. Therefore, before any collection vehicle type or body size can be chosen it is essential to know the density of the wastes to be collected. In many cases, compactor trucks are not selected for their ability to compact waste, but for their convenient loading arrangements and for their volumetric capacity. Conventional open-top trucks having equivalent capacities are very difficult to load, but there are designs which enable convenient and efficient loading. One is the front-loading "Tipack" design (Section 7.6.3), which

Table 7.4 Comparative capacity of two refuse vehicle types as a function of waste density

Item (weights in kg)	Waste density (kg/m^3)	Vehicle type: Compactor	Vehicle type: Non-compactor	Extra capacity of non-compactor	Notes
Permissible GVW		13,000	13,000		
Body Weight		3,500	1,500		
Chassis & cab weight		4,500	4,500		
Maximum waste load		5,000	7,000		= GVW – weight of chassis and body
Maximum payload (kg) at various densities	100	5,000	2,000	-60%	For non-compaction truck, the load is limited by volume
	250	5,000	5,000	0%	
	400	5,000	7,000	+40%	Both limited by weight

would require a slightly longer chassis for the loading platform (which could also be used for transporting the crew). Another is the fore-and-aft tipper, which has a convenient loading height but is not currently in regular production (Section 7.6.4). A third is the side-loading binlift system (Section 7.6.5) and a fourth is the crane-tipper (Section 7.6.6). All of these allow efficient loading of large, non-compacting bodies. A further arrangement, uses small transfer stations with pits for open-top containers into which small primary collection vehicles (human-, animal-, or engine-powered) discharge their wastes (see Section 8.2.4). All of these non-compacting vehicles have large bodies and can be loaded and unloaded in efficient ways, and have many advantages over compaction vehicles in low- and middle-income countries where the wastes have densities of 250 kg/m^3 or more when loaded into a truck body.

The following sections give a brief review of the various types of compaction vehicles whilst strongly recommending that they are only used in exceptional circumstances, such as for commercial areas in larger cities which are large enough to justify a special collection service and where there are low density wastes to be collected.

7.8.2 Rear-loading compaction plate compactors

The most common refuse collection vehicles in industrialised countries use rear-mounted compaction systems with large hoppers and compaction plates, which sweep the refuse from the hopper into the truck body (see Figure 7.22 and Photos 7.17). The waste is compressed by the compaction mechanism against a movable ejector plate which gradually moves forward under the pressure of the waste, thus maintaining a constant pressure on the waste. To discharge the load the compaction mechanism is lifted out of the way by hydraulic cylinders and the ejector plate (also called the pressure plate) pushes the wastes out of the rear of the vehicle. Typically, a waste compaction body and mechanism of this type weighs around 3,500 kg and this higher weight greatly reduces the amount of waste which can be carried without overloading the truck.

In a developing country, the initial density of the wastes before loading into the truck may be in excess of 500 kg/m^3 and after compaction it may increase to as much as 700 kg/m^3. However this is only a very small volume reduction (less than 30%). More waste could be carried in a larger body without compaction as illustrated in Figure 7.21.

In order to have a low loading height, the loading hopper and the associated machinery must be behind the rear wheels, with the result that most of the weight of the compactor truck is concentrated towards the back of the truck. If the compacted wastes have a density of almost twice what the compactor trucks were originally designed for, this means that the trucks must be fitted with very small bodies to prevent overloading. This, in turn, means that the bodies must be shortened, with a correspond-

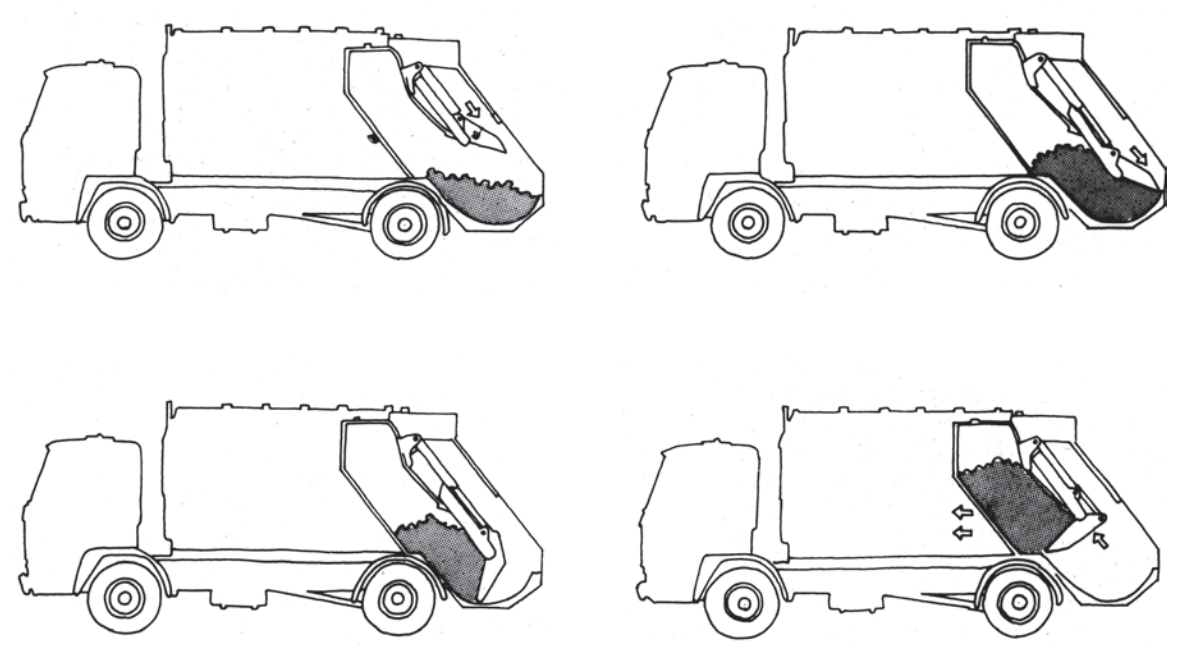


Figure 7.22 Rear-loading compaction plate compactor. Suitable for low-density waste including large items and for use with binlift. Intermittent loading.

This truck was fitted with a small body because of the high waste density in Colombia. It then required a 1 ton ballast weight at the front to pre-vent it falling over backwards when unloading, thus further reducing its load capacity.

Photo 7.18 Weight distribution problems

ing reduction in the wheelbase of the truck, in some cases to such an extent that there is not enough weight on the front axle to give adequate steering, and it is seldom possible to achieve the maximum permitted GVW without overloading the rear axle. Sometimes the concentration of the load at the rear is so great that the front wheels of a loaded compactor truck lift off the ground when unloading, or when starting on an upward slope. The problem of weight distribution may be worst when the vehicle is partially loaded and all the waste is in the back half of the body. It is not uncommon to find that ballast (up to 1,000 kg) has been added to the front of the truck, further reducing the waste load since the GVW is unchanged (see Photo 7.18). Special asymmetric rear springs may be fitted to these trucks in an attempt to improve the weight distribution by allowing the rear wheels to be located as close to the rear of the truck as possible.

The advantage of these rear-mounted hydraulic systems is that they can handle large bulky items (although these are seldom found in developing countries) and that they allow very low loading heights and are consequently easy and fast to load. However, for high-density wastes these advantages are not enough to justify the high capital, operating and maintenance costs, and the reduced load capacity due to the weight of the compaction mechanism. In addition, they have a short life as the large number

a) The low loading height and large hopper are big advantages

b) The waste is pushed out hydraulically by the compression (or ejector) plate

Photos 7.17 Rear-loading compacting plate compactor truck
Photo (a) Dennis Eagle

Photo 7.19 Compactor truck with binlift

Photo 7.20 When the compaction mechanism cannot be repaired it can be taken off

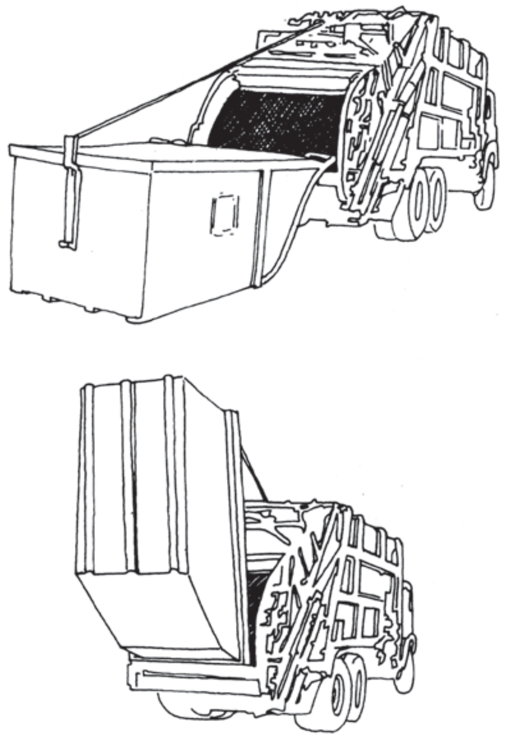


Figure 7.23 Large rear-loading compactor truck emptying large skip container

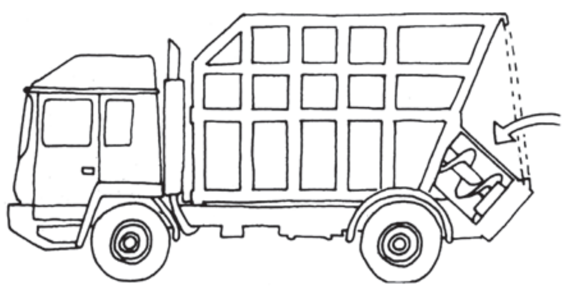
of sliding components and exposed hydraulic cylinders are subject to excessive wear when used for handling the abrasive wastes commonly found in developing countries. They are also subject to "anaerobic" corrosion in the many crevices in the body due to the high organic content of the wastes in most developing countries.

Rear-loading compactor trucks are often fitted with hydraulic mechanical lifts that lift and empty bins into the rear hopper. Some mechanisms can lift two smaller two-wheeled bins independently or together, some lift larger four-wheeled containers, and some are able to handle both types of bin. Hydraulic or electric winches are also used to lift and tip larger containers. Many trucks fitted with binlifts can also be loaded manually.

There are also large rear-loading compactor trucks that are designed to lift and empty large skip containers with capacities of up to 10 m^3. This type of vehicle is normally fitted with hydraulically operated stabilising "feet" at the rear to prevent the front wheels lifting off the ground when large skips are being lifted. The lifting mechanisms may be winches or large hydraulically operated arms (see Figure 7.23). Such vehicles may also be loaded manually with dustbins when required. These vehicles, which use double rear axles, are very costly and require clear access for loading. The complex machinery on the vehicle, together with the fact that the moving parts in the body are exposed to the wastes, make them unsuitable for use in developing countries, despite their high potential productivity. Some models may not be suited to the high density wastes often found in developing countries. This type of vehicle may, however, prove feasible when used in conjunction with compatible small-capacity primary collection vehicles, such as micro-trucks and auto-rickshaws, deployed to collect the wastes from various residential areas with narrow streets and transport them to transfer points on wide roads where the containers are located. The primary collection vehicles should have high-tipping unloading mechanisms that can tip the waste directly into the large skip containers. At these transfer points there should be enough space for the large compactor vehicles to operate. Careful consideration should be given to costs and waste characteristics.

7.8.3 Screw compactor

This form of compaction vehicle is more relevant to the needs of developing countries than either the rear- or the side-loading hydraulic compactors. A rotating screw forces the waste into the body, while it compresses and fragments it (Figure 7.24). This type was very popular in Europe in the 1960s and 1970s when the wastes there were more abrasive than at present. Although the screw is subject to wear, it is the only moving part in contact with the wastes and is very easily removed for reconditioning with only an electric welder and hard facing welding rods. (It is normal to have a spare screw available so that downtimes are minimised). The screw compaction mechanism is lighter than the hydraulic compaction mechanism, thus permitting greater payloads to be carried and giving a good weight distribution, allowing loads of 1,000 kg to 1,500 kg more than in the rear-loading compaction plate vehicles. It is suited to handling loose, abrasive wastes but is not suitable for handling large bulky items due to the small screw aperture. This is why it lost its popularity in



Suitable for low-density loose and bagged wastes. Continuous loading

Figure 7.24 Rear-loading screw compactor

Europe. Most of the compaction takes place in the mechanism itself instead of in the body of the vehicle, so that a moving ejector plate is not required for discharging. The rear section is raised and the body is tipped to discharge the load. The resulting vehicle is, therefore, light and simple, however it requires sophisticated equipment for the manufacture of the gearbox and screw and so may not be suitable for local manufacture in many countries.

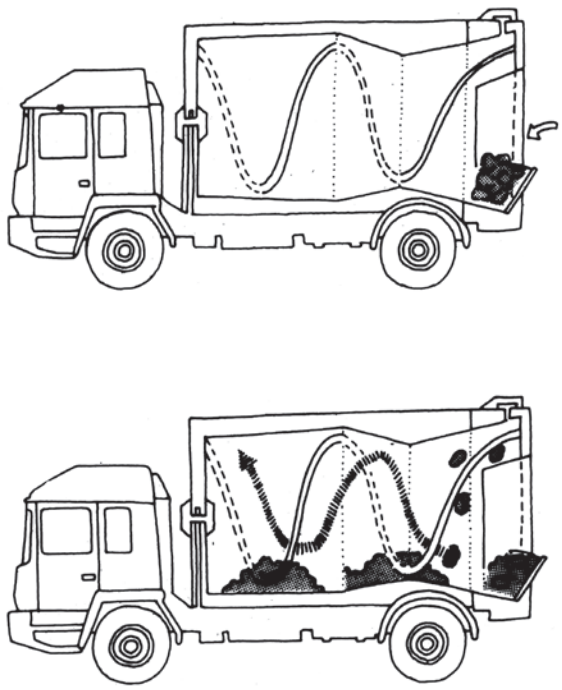
7.8.4 Rotating drum compactor

This vehicle is also more suitable than compaction plate vehicles for handling small items and dense wastes. The refuse is loaded at the rear of the truck into a large rotating drum from where it is pushed forward by the helical blades inside the drum as it rotates (see Figure 7.25). The reduction in volume of the wastes is achieved as much by the pulverizing effect of the wastes rolling around inside the body as by compaction. Weight distribution between the front and rear axles is not a problem with this type of body. The load is discharged by lifting the rear gate and reversing the direction of rotation of the drum. Unloading takes a little more time compared to other types of compactor and a large vehicle may need to move forward several times during unloading (Photo 7.21). This vehicle can, however, have excessive wear problems with abrasive wastes and the circular shape of the body reduces the volume capacity.

At the time of writing (2008) this type of body is still being manufactured and widely used in Europe and in middle-income countries (such as Oman, where a fleet of more than 80 trucks of this kind are employed). It can be used with binlifts and manual loading, although the loading height (about 1.6 m) is higher than that of compaction plate type compactors. However experience of this type of body in other countries (such as Tanzania) has not been good.

7.8.5 Paddle compactor

In this type of vehicle, a paddle sweeps left and right in a semi-circular hopper, alternately sweeping the refuse into each side of the body (see Figure 7.26). Loading can be either at the rear of the vehicle or behind the driver's cab (Photo 7.22). The latter loading system is particularly suitable for mounting on small trucks, because it permits loading from both sides and gives a very good weight distribution with a lightweight body, allowing comparatively large payloads to be carried on a small truck chassis. It is particularly suitable where there are narrow streets or heavy traffic conditions. The loading height of paddle compactor vehicles is determined by the height of the truck chassis, so that on most small trucks the loading

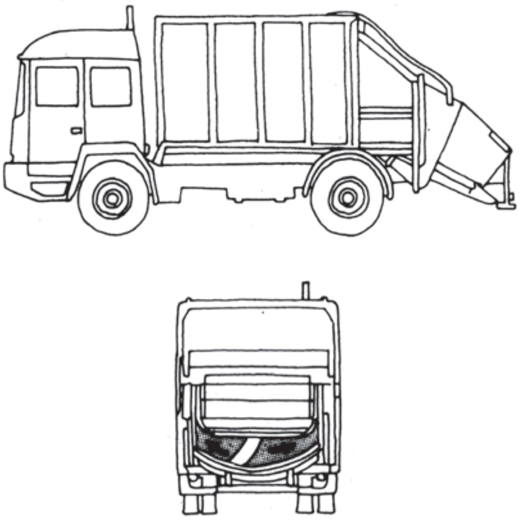


Suitable for low- and medium-density wastes. Reduces volume by pulverising. Susceptible to wear from abrasive wastes. Continuous loading

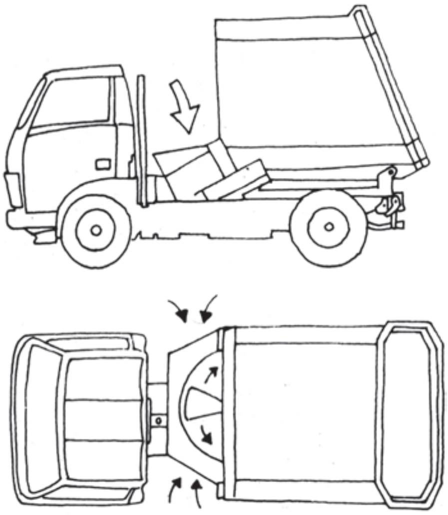
Figure 7.25 Rotating drum compactor

Photo 7.21 Rotating drum truck unloading

Photo 7.22 Small side-loading paddle compactor



a) Rear-loading



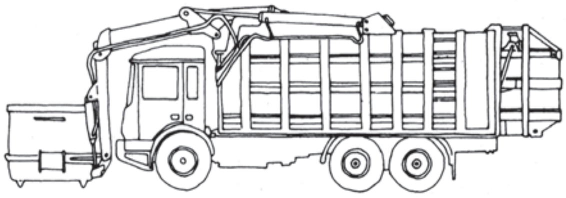
b) Side loading Suitable for fitting to smaller trucks

Figure 7.26 Paddle compactor truck. Suitable for loose and bagged waste. Continuous loading.

height is conveniently low, but on large trucks with large diameter wheels and high chassis, the loading height is higher than on many other compaction vehicles. Paddle compactors have been used successfully in the Ivory Coast but have not become popular in other developing countries where non-compaction systems would be more appropriate.

7.8.6 Front-loading compactor

In this type of vehicle, waste containers of 1.5 to 3 m^3 capacity are picked up by forks located at the front of the truck, lifted over the driver's cab and tipped into the top of the front of the compactor body where the waste is compressed rearwards (see Figure 7.27 and Photo 7.23). This vehicle, especially when used on a multi-shift basis,



A costly system requiring a large area for manoeuvring. For low-density wastes.

Figure 7.27 and Photo 7.23 Front-loading compactor

has very high productivity, and often requires no labourer to assist the driver. They cannot be used for kerbside collection and manual loading.

These vehicles use double rear axles, are very costly and require clear access for loading. The complex machinery on the vehicle, together with the fact that many of the moving parts of the machine are exposed to the wastes, make them unsuitable for use in developing countries, despite their potential for highly productive operations. The front forks are generally not designed for high density wastes and the front axles of the vehicle may need reinforcing. Space restrictions and road conditions, in particular, may prevent their use in many urban areas of developing countries.

7.8.7 Comments on loading systems for compactor trucks

The screw, rotating-drum and paddle-type compactors are "continuous-loading" systems so that, even with small mechanisms, speedy loading can be ensured. Rear-loading compaction plate compactors, however, are usually "intermittent-loading" systems, where hydraulic loading has to be suspended during the compaction cycle. For this reason, intermittent-loading compactors are fitted with large loading hoppers, and this permits bulky waste items to be loaded into the vehicle, which may not be possible with small hoppers. However it is only very rarely that large items are found in developing country wastes so that this is not a significant advantage.

7.9 EXCHANGED CONTAINER SYSTEMS

Among the many different types of container pick up vehicles are the following:

7.9.1 Tractors and containers

a) Container pickup – Tractors can be used to pick up containers using the standard lift arms on the back of a tractor (Figure 7.28 and Photo 7.24). In Gaza, for example, a container lifting frame was designed, manufactured and fitted to small agricultural tractors to bring containers from the areas served by narrow lanes to a main road where they are placed by the roadside to be later picked up by the crane system shown in Figure 7.17. Ballast weights were needed at the front of the tractor to counterbalance the rear loads.

b) Trailed container pickup – Tractors in the 40–60 hp range can be used to pull container pick-up trailers of up to 10 m^3 capacity with loads of up to 5,000 kg. Larger tractors can be used for pulling large transfer trailers with capacities that may exceed 20 m^3.

The tractor hydraulic system is used for both picking up the container and for tipping the wastes without the driver having to leave the tractor seat. The trailer is reversed into position at the container that is full and ready to be removed. The hydraulic system on the tractor then operates a mechanism on the trailer that picks up the container so that it can be transported to a transfer station, treatment plant or disposal site (Photo 7.25). At this destination the tractor uses the trailer mechanism to tip the container so that its contents are discharged (Figures 7.29 to 7.31). The waste may be discharged at ground level or directly into a container or vehicle if the trailer is equipped with a special high-tipping mechanism which raises the container before tipping it (Figure 7.32, Photo 7.26 and Box 5.2). The container is then lowered to the travelling position and taken back to where it came from or transported to another collection point from where the next full container is taken away. Container pick-up systems that are pulled by tractors are very cost effective where there are short or medium length haul distances and a variety of different systems are available.

Typically a tractor and container trailer costs no more than one half the cost of a roll-on or hooklift container truck with the same capacity, (but the speed of the tractor would be significantly less on a long distance). Cost calculations may be expected to show that tractors with container trailers are more economical for haul distances of up to 15 km.

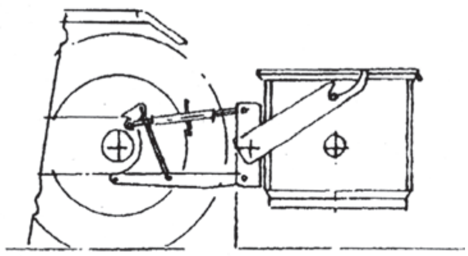
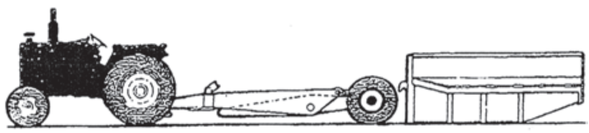
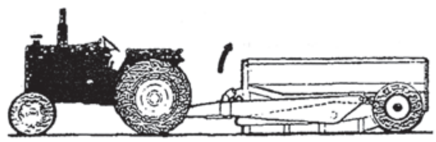


Figure 7.28 Container pickup on tractor

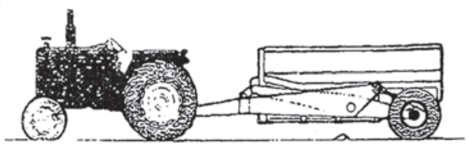
Photo 7.24 Loading container behind tractor



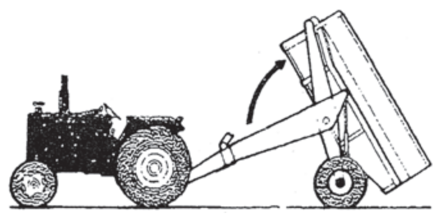
a) approaching container



b) picking up container



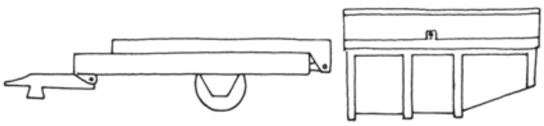
c) transporting container



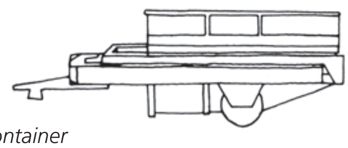
d) emptying container

This scissor-lift system is manufactured in several countries including South Africa and Kenya. Load capacity 6 tons. Requires 50–60 hp tractor. Can be operated from tractor seat.

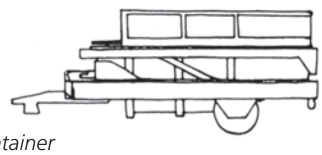
Figure 7.29 Scissor-lift container system



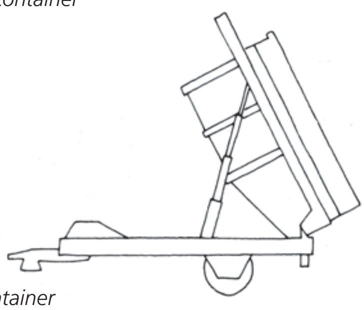
a) approaching container



b) picking up container



c) transporting container



d) emptying container

A twin axle version can carry up to ten tons behind a 90 hp tractor.

Figure 7.30 Parallel-lift container system

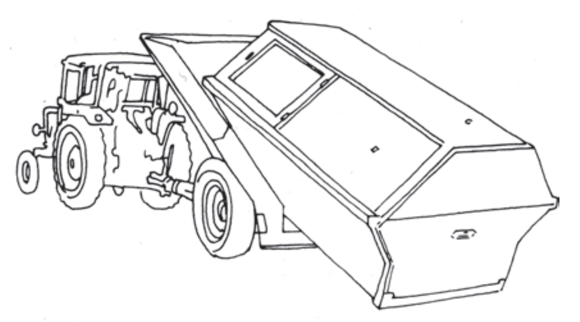
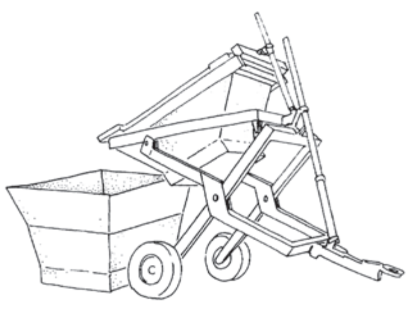


Figure 7.31 A very simple winch-on system can be used as a container lift or a conventional trailer



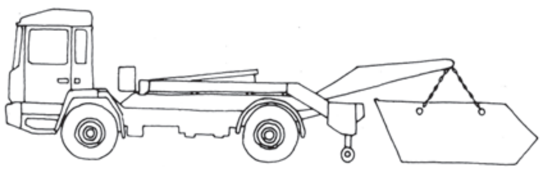
This trailer picks up 3 m³ community containers and empties them into large 8 m³ transfer containers. It is also capable of picking up, transporting and emptying the larger containers, when used with a 60 hp tractor. It is a low-cost and practical system for smaller towns

Photo 7.26 and Figure 7.32 High-tipping scissor lift trailer

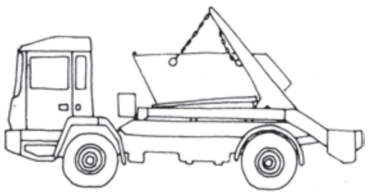
7.9.2 Skiplift (load lugger) vehicles

There are two systems that are based on standard commercial truck chassis in the 5 to 15 ton GVW range. One is the skiplift system, which is also known as the "load lugger", "bucket lift" or "dumper placer" system and is shown in Figure 7.33 and Photo 7.27. The other system is described in Section 7.9.3. The skiplift system uses two hydraulically-operated lifting arms and chains to pick up the containers. The driver or an assistant must get down from the truck to attach the chains to the container so that the container can be lifted onto the deck of the truck. The container is tipped to empty by restraining the rear of the container while the lifting arms raise the front.

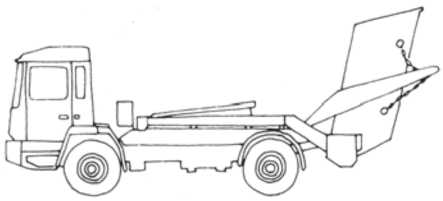
The width of the container is restricted by the space between the two lifting arms and the height is limited by the cross bar joining the tops of the arms. These restrictions on width and height limit the maximum container size to about 6 m^3, so that a full payload can usually only be obtained when the container is filled with high-density wastes such as construction wastes or some types of industrial waste. For this reason they are often considered to be unsuitable for municipal wastes, except perhaps where the fast turnaround and short travel times reduce the importance of the weight of the load.



a) picking up the container



b) transporting the container



c) tipping the container

The size of the container is limited by the width between the lifting arms and the height under the crossbar at the top of the lifting arms.

Figure 7.33 Skip lift or load lugger system

Photo 7.27 Skiplift truck discharging load

Container pick up vehicles typically take less than two minutes to pick up and set down containers and an equal amount of time to tip their load. Therefore, if the skip size and vehicle GVW are well matched (considering the type of waste being carried), skiplift trucks can be extremely productive, handling ten or more loads each day, depending on the haul distances.

Skiplift trucks have hydraulically operated stabilising legs at the rear to stop the front of the vehicle lifting when heavy containers are being lifted. These legs are sometimes designed in such a way that they are damaged if the driver forgets to raise them before driving off.

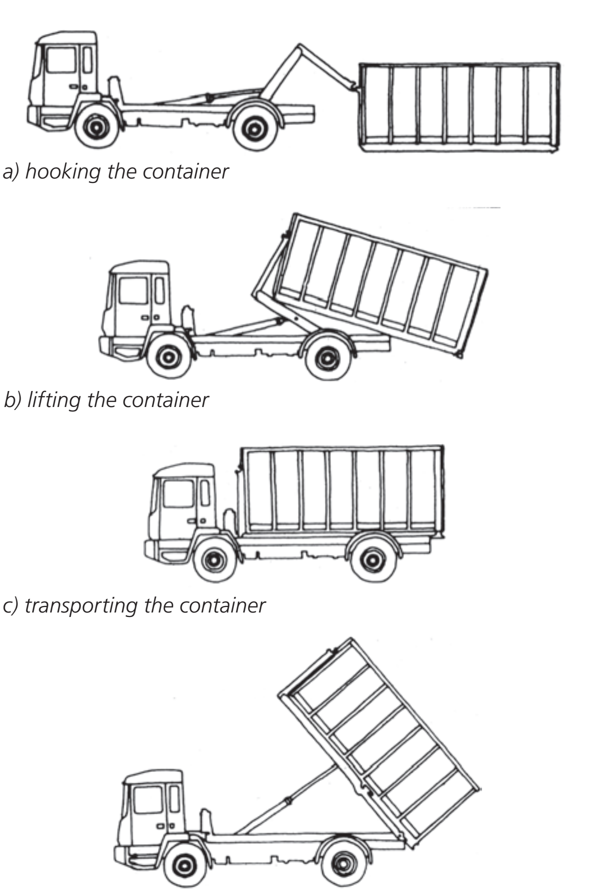
Skip containers come in a range of shapes and sizes. Containers used for municipal solid waste are often enclosed, with large and small openings that can be closed with lids. Large lids are often damaged when the skips are tipped to empty – hanging lids are sometimes bent during unloading when they come into contact with the ground or with a pile of waste. If open containers are used for municipal wastes they should be covered by a net or tarpaulin when they are being transported, and this operation significantly increases the pick-up and emptying times. Tapered, open containers can be stacked, and some trucks are able to carry two loaded skip containers, one inside the other, when the lower one is not completely full.

Skiplift trucks sometimes pull trailers that carry a second skip container. However, this can cause considerable delays at the disposal site as the trailer must be detached for emptying the containers. Recent designs of truck can pick up two small skips – one from the side, and another from the rear.

7.9.3 Roll-on and hooklift (arm-roll) systems

Roll-on and hooklift trucks lift containers onto their decks by lifting and pulling the front of the container. The roll-on system uses a ramp type of lifting frame and steel cables to winch the container up the frame. The driver or an assistant must attach these cables. Although still commonly used in the United States, in most other countries this system has been overtaken by the hooklift system which can be operated by the driver without his having to leave the truck cab (Photo 7.28 and Figure 7.34). The hooklift system has a hydraulically-operated arm that is fitted with a hook which engages a loop on the front of the container. In both systems the rear of the container rolls on steel rollers and containers are emptied by tipping.

Both the roll-on and hooklift systems can pick up containers which are the full width of the truck and there are no crossbars or other obstructions to limit the height of the load. They can therefore pick up much larger capacity containers than the skip lift system and so they are more suitable for municipal wastes.



a) hooking the container

b) lifting the container

c) transporting the container

d) emptying the container

No restrictions on width or height of the container

Figure 7.34 Hooklift system

Photo 7.28 Hooklift truck loading open container

Hooklift and roll-on containers are capable of handling up to 20 m^3, according to the payload capacity of the truck. Small 5 ton GVW hooklift trucks with 4 m^3 containers have been successfully employed in Yemen to serve smaller communities. They require little manoeuvring space. With three- and four-axle trucks, containers up to 30 m^3 are possible, but such systems are extremely costly and rarely, if ever, appropriate for developing countries, unless as secondary transport vehicles which must cover very long distances.

There are various types of hooklift container, and it is one of the advantages of the system that different types of container can all be handled by one type of truck. Covered containers with a number of small lids in the cover and open containers with sides about one metre high can be used as community bins and for receiving loads from primary collection vehicles. Open containers with sides over 2 m high can be loaded by wheeled loaders and at split-level transfer stations (Sections 8.2.2 and 8.2.3). Containers used for long-distance transport can be loaded by static compaction systems which compress the waste into the containers (Box 8.1). Open containers should be covered with a net or tarpaulin when the loads are being transported, and spreading this cover over the load adds to the pick-up and unloading time. There are various systems that allow an operator standing on the ground to spread a cover over the load in a high container, but some of these systems are not very robust and care must be exercised to ensure that the cover is not torn by waste as it slides down the container during unloading.

With all the above systems (skiplift, roll-on and hooklift) the truck must be able to align itself with the container and this means that a large amount of clear space is required, including manoeuvring space for the truck. (Hooklift trucks can pick up one end of a container without being completely in line with it and roll it a short distance until it is precisely lined up before lifting it onto the deck of the truck.) An attendant is usually responsible for each container to make sure that the access is clear and to sweep up any loose wastes around the container. The length of the space required by a 6 m long container is calculated to be 23 metres in Table 7.5 and Figure 7.35. An 8 m container would require 27 m. The space requirement may be reduced if the container is parked at an angle and the truck can block the street when it is picking up and putting down the container, but obstructing the traffic in this way may be unacceptable.

The truck must also be able to deposit an empty container each time it picks up a full one (requiring a width of 6 m if the containers are side-by-side when they are being

Table 7.5 Estimating length of space required for a 6 m hooklift container

Length needed for:	container	hooklift arm	truck body	truck cab	manoeuvring	TOTAL
Length required (m)	6	2	7	2	6	23

exchanged, so the minimum dimensions for the location site for a roll-on or hooklift container is 23 metres x 6 metres. This greatly limits the use of such containers in city centre areas.

7.9.4 Small container shuttle

Another type of container-hoist vehicle, known as the *Micrabin*, designed to carry small containers for short distances and operate under difficult road conditions in congested areas, is being used very successfully in The Maldive Islands. This vehicle is based on a small construction site dumper with a modified chassis, and can operate in congested areas and narrow streets (see Figure 7.36 and Photo 7.29). It uses a 9 hp (6.7 kW) single cylinder diesel engine with a simple three-speed gearbox, with a maximum speed of 20 km/h. Hydraulically operated arms pick up 2.0 m^3 containers of wastes so that the vehicle can transport them to the special boat which then ferries the containers to an adjoining island where they are emptied before being returned. With a trip time of less than 15 minutes, one vehicle can collect 25 to 30 containers per day.

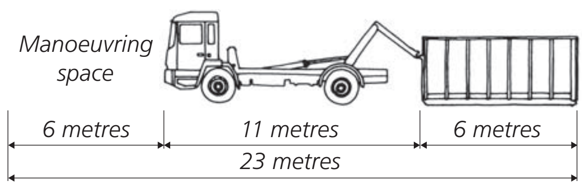
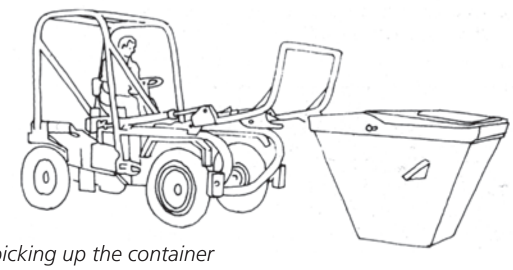


Figure 7.35 A hooklift truck to carry a 6 m long container requires a minimum clear space of 23 metres by 6 metres to allow for depositing an empty container and picking up a full one.

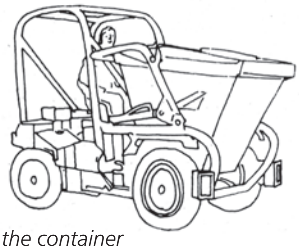
a) picking up container

b) transporting container

Photos 7.29 Micrabin container vehicle made from standard dumper truck components

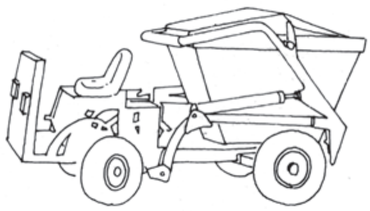


a) picking up the container



b) transporting the container

c) emptying the container



d) alternative location for the container

Figure 7.36 Container system based on construction site dumper truck

7.10 SUMMARY

A resume of comparative characteristics of non-containerized refuse-collection vehicles is presented in Table 7.6 Recent experience suggests that small transfer stations (see the following chapter on waste transfer) can greatly facilitate the use of small collection vehicles in both city centres and residential urban areas. In very many situations the most efficient and lowest cost collection system consists of small motorised vehicles or even handcarts or tricycles bringing the wastes to small transfer stations.

The choice of any system must depend on local conditions, including haul distances from the collection area to the disposal site, local labour costs, access to foreign exchange, fuel costs, street widths and facilities for local manufacture of bodies. If scores of 1 to 5 are awarded against each of the factors (after perhaps weighting each factor according to its relative importance) for each of the systems being considered, and the points awarded are added up, the total scores can be used as a rough guide for system selection. Where haul distances are long, it is often most economical to combine short- or medium-range systems, which can collect wastes and bring them to a transfer area, with a container system for long-distance haul to the disposal site.

Some of the types of non-compaction body that have been presented in this chapter are not currently being manufactured. In most cases the detailed designs already exist, so the inputs needed to begin to manufacture them are to find these designs, get permission to use them, and fabricate and test the first of the production run. This requires some finance, expertise and time. The costs of developing a type of non-compaction waste collection body that is particularly suited to local conditions may appear to be beyond the scope of a particular municipal budget or a small international co-operation project, but experience in Gaza[34] has clearly demonstrated the benefits

34. *See Borno [2000]*

Table 7.6 A summary of comparative characteristics of typical non-containerized refuse-collection vehicles

Vehicle type	See Section number	Gross vehicle weight (tons)	Body volume (m³)	Operating range	Loading speed	Labour requirement	Capital cost per m³ waste	Fuel & maintenance cost per m³ waste	Economic life of vehicle	Suitability for narrow streets	Suitability for local manufacture of body
Small vehicles											
handcart	7.3.1	-	0.4	short	fast	high	low	low	short	good	yes
pedal tricycle	7.3.1	-	0.5	mid	fast	high	low	low	short	good	yes
animal cart	7.3.2	-	2.0	mid	fast	mid	low	low	mid	good	yes
autorickshaw	7.3.4	2	3	mid	fast	mid	low	low	mid	good	yes
Tractor & trailer	7.4	11	6	mid	mid	mid	mid	low	long	mid	yes
Non-compacting											
high side open body	7.6.1	10	10	long	slow	high	high	mid	mid	poor	yes
side loading roll-top	7.6.2	6	6	long	mid	mid	high	mid	mid	mid	yes
front loading "Tipack"	7.6.3	8	10	long	slow	mid	high	mid	mid	mid	yes
fore-and-aft	7.6.4	8	10	long	fast	low	mid	mid	mid	mid	yes
side-loading binlift	7.6.5	8	10	long	mid	low	mid	mid	mid	mid	yes
crane tipper	7.6.6	14	12	long	fast	low	mid	low	long	poor	part
Semi compaction											
side loading, barrier	7.7.1	9	10	long	slow	mid	mid	mid	mid	mid	yes
fore & aft with plate	7.7.2	9	10	long	fast	low	mid	mid	mid	mid	yes
Compaction											
rear loading hydraulic	7.8.2	14	10	long	fast	low	high	high	short	poor	no
screw compactor	7.8.3	14	10	long	fast	low	high	high	short	poor	no
rotating drum	7.8.4	14	10	long	fast	low	high	high	short	poor	no
paddle	7.8.5	7	6	long	fast	low	high	mid	short	mid	no

Notes: "Suitability for narrow streets" includes manoeuvrability and operation in unplanned areas, "mid" means medium of developing a waste collection body to suit local needs. As experiences with the Tipack in southern Africa and the side-loading binlift truck in China have shown, there can be a large market and widespread benefit as a result of investing in the local manufacture of an appropriate body. Perhaps the lack of initiative in this aspect of solid waste management is a result of poor leadership and co-ordination in solid waste management at the national level. Funds invested in setting up the internal manufacture of relatively simple truck bodies could generate a huge benefit in terms of lower service costs and improved reliability in scores of cities in the particular nation and in the surrounding region. Private enterprises may be unwilling to make the speculative investment needed to start local production of appropriate truck bodies because of the widespread use of compactor trucks and inefficient open trucks, but with national leadership and more thoughtful selection of vehicle types, the demand for more efficient vehicles could be stimulated.

Summary points

- There is a very wide range of vehicles to choose from, so the selection should be made after careful consideration by open-minded technical experts who are prepared to consider new types of vehicle if there are good reasons for using them.
- Small vehicles often have distinct advantages over large ones and can be very efficient when used with small transfer stations.
- Waste density and method of loading are major factors to consider when selecting waste collection bodies.
- The final decision regarding vehicle type should include comparisons of the cost of collecting each ton of waste.
- Simple vehicles based on chassis (both manufacturer and model) that are widely used locally are preferable because they offer low maintenance costs and good reliability.
- Real benefits can be expected from investing in local manufacture of well-designed bodies.

TRANSFER

8

8.1 INTRODUCTION

The requirements of a vehicle for collecting wastes are very different from the requirements for transporting the wastes that it has collected to a transfer station, disposal site or processing plant.

For collecting, the vehicle should be small and manoeuvrable for working in narrow streets and heavy traffic and it should have a low loading height for fast and hygienic loading. It should have a crew cab with easy access or a safe standing platform for the loaders. When operating within urban areas, the traffic speeds and speed limits will restrict its speed to no more than 50 kph, so there is no need for high-powered and high-speed vehicles. These requirements favour the selection of a small vehicle with a small engine for fuel economy and less pollution. Where there are low-density wastes, a compaction mechanism may be required to reduce the volume of the wastes so as to enable full loads to be carried, although generally in developing or low-income countries where waste densities are high, there is no reason for compaction. A loading mechanism may be required if the wastes are collected from bins or containers.

For transporting the wastes to the disposal site a large vehicle is required with a higher-powered engine for fast travel. There is no need for the crew cab or platforms and no need for either a compaction mechanism or a loading system. It is clear that the requirements when collecting are very different from the requirements for transport.

There may be restrictions on the movement of heavy trucks in the city centre areas during business hours to reduce traffic congestion. Transfer provides the opportunity, for storing wastes that are collected during the day so that they can be transported to the disposal site at night, or vice versa. Very often bin or bag collections take place in residential areas during the day time when there is less traffic and fewer problems with parked cars. However, waste collection from the city centre areas often takes place at night when there is less traffic congestion. Block collection or other "bring" systems must operate at times when the householders are at home. Collection systems often work two shifts, collecting in residential areas during the daytime and in city centre areas at night in order to maximise the vehicle utilisation.

In urban areas where the haul distances from the collection areas to the disposal sites are short, a compromise vehicle may be appropriate, combining some of the features required for collection and some for transport. However, as with all compromises, such systems are not very efficient for either function. Large collection vehicles cause traffic problems in the collection areas and transport must take place at the same times as collection. The collection service is disrupted while the vehicle is travelling to the disposal site for discharge. Two or more small vehicles may be more efficient than one large one, as illustrated in Table 7.1.

Unless the haul distances to the disposal site are very short, a transfer system (whereby small and manoeuvrable collection vehicles can transfer their loads to larger transport vehicles) will be more efficient. There are a number of ways in which waste can be transferred from small collection vehicles to large transport vehicles. The most common methods are discussed in Section 8.2. Most of these require large areas of ground and must be located away from commercial and residential areas to avoid nuisances. However, modern pit-and-hoist type *small transfer stations* (STS) require very little space and can be located close to where the wastes are generated, thus enabling lower-cost collection systems to be used. Several *small transfer stations* in residential and city centre areas can take the place of a single large transfer station, thus greatly reducing primary haul distances.

8.2 TRANSFER SYSTEMS

8.2.1 Rendezvous system

This method of transfer has no infrastructure for the transfer operation. Instead the operators of the primary collection vehicles are instructed to wait for the secondary transport vehicle at a particular location and at a particular time. Whilst no capital investments are involved in this arrangement, there are very significant operational deficiencies resulting in high operational costs per ton of waste transferred. Either the truck waits for the primary collectors to come, or the primary collectors must wait for the truck. Whichever happens, time is wasted and productivity suffers. A clear example of the problems and consequences of this system is given by the case of primary collection with tricycles in Ho Chi Minh City in Vietnam, which can be found in Section 7.3.1.

The same applies to a more mechanised version of this system that uses small primary collection vehicles that have high-level tipping bodies to discharge their loads directly into the loading hopper of a large, rear-loading compactor truck. Compactor trucks are not designed to be secondary transport vehicles for carrying waste over long distances, and they are expensive to run and maintain, in addition to the other disadvantages of using compactor trucks in developing countries (Section 7.8.1), but this option may be worth considering in some circumstances provided that the total cost per ton is competitive.

8.2.2 Loading from the ground

At its most basic, a transfer station may consist of no more than a flat piece of ground onto which the wastes are dumped by the primary collection vehicle and then loaded into the transport vehicle. On a small scale the wastes may be loaded manually, using rakes and baskets or shovels or forks, but this method is inefficient and unhygienic. Often wheeled loaders (Photo 8.1) are used to load these wastes into tipping trucks or large containers, but this method may be inefficient if the wheeled loader is only working for a short time each day because of the small quantity of wastes or long periods when the trucks are travelling to and from the disposal site. This method of transfer should only be considered as a short-term emergency measure, because of the mess it creates and the cost of operating the front loader. Solid waste is not a transitory phenomenon – it will be with us for the foreseeable future, so it is reasonable to make investments that maximise efficiency and minimise pollution in the long term. Waste management sites of this kind reinforce the belief that all waste management facilities are dirty, unhealthy and untidy and so they strengthen public opposition to all new solid waste management facilities.

8.2.3 Split level transfer stations

Conventional split level transfer stations normally have ramps which the primary collection vehicles drive up to discharge their loads, either directly into containers or secondary transport vehicles below (Photo 8.2) or into stationary compactors which compact the waste into hooklift containers or truck bodies. The ramp must not be so steep that a loaded vehicle cannot go up it – this is of particular concern when human or animal power is used.

Simple roadside transfer stations may comprise a ramp and a container or trailer.

Sometimes conveyors and elevators are used to raise the wastes into hoppers so that the primary collection vehicles can discharge at ground level but these simply add to the complexity of the transfer station with additional places for rodents and insects to hide and additional odour problems. A lift (elevator) system was developed in Da Nang (Vietnam) so that handcarts could be raised to the upper level from where the wastes were discharged by gravity by tipping the handcarts to transfer the loads directly into secondary transport trucks waiting below.

There are a number of fundamental problems with all types of ramp systems including:

There are many problems with this system including smells, insects, rodents, litter, and poor vehicle utilisation due to long delays while the secondary transport vehicles are being loaded.

Photo 8.1 Wheeled loader transferring wastes from the ground into a large semi-trailer

Box 8.1 Additional information

Containers at transfer points

This system avoids keeping expensive trucks waiting while their bodies are filled, and minimises the waiting time of the primary collection vehicles. The primary collection vehicles discharge their loads into large containers which are located in or close to the collection areas. The containers are picked up by a truck fitted with a hooklift or other container pickup mechanism. The container truck brings an empty container and leaves it alongside the full one before picking up the full container and hauling it away for emptying.

There are a number of problems with this system including:

- The large space requirement at each transfer point due to the manoeuvring space required by the container vehicle and the need to be able to place an empty container near the full one.
- There is a requirement for special high tipping primary collection vehicles which can discharge their loads directly into the containers, which may have sides which are at least 2 m high. Ramps can be used so that the primary collection vehicles can drive up to the height of the tops of the containers and tip their loads in the conventional way, but this further increases the space requirements.
- The efficiency of the secondary transport vehicle is reduced by the weight and cost of the container pickup mechanism and the heavy weight of the containers which together reduce the vehicle's load carrying capacity.
- Difficulties with cleaning down the transfer points as there will at all times be a full or empty container at each location. As soon as the full container starts to be lifted, the cockroaches and rodents will run for safety under the empty container alongside, adding insect and rodent nuisances to the smell problem. Wash-down facilities (hose, paved surfaces and drain) are essential at each container point if smells are to be avoided, and even then it is difficult to wash down properly because one container is always present.
- There is very little storage capacity at this type of transfer station. The number of collection vehicles bringing waste into the site tends to reach a maximum and then drop until the next peak, whereas the removal of waste in large secondary trucks is relatively constant during working hours. This mismatch of input and output may necessitate considerable storage.

If the wastes have a low density it may be appropriate for large quantities of waste to use static compactors which compact the waste into closed containers using a hydraulically operated ram located at the base of a hopper into which the waste is tipped by the primary collection vehicles.

Containers with integral loading and compaction mechanisms are available but these are not appropriate for the high-density wastes found in developing countries. Furthermore, they have reduced load capacities because of the weight of the heavy compaction mechanism and have considerable problems with organic wastes or in rainy seasons when the compaction mechanism squeezes corrosive and noxious leachate out of the wastes.

- These systems take up large areas of land so they are usually located away from the city centre and densely populated areas where land values are high, and constructed in marginal areas with lower land values. This, in turn, results in excessively long travel distances for the primary collection vehicles resulting in reduced collection vehicle efficiencies and the impossibility of using certain short-range collection vehicle options such as handcarts and tricycles.
- Noise and smell problems are common unless the site is kept scrupulously clean, and paper and plastic may be blown into neighbouring properties. For these reasons residents can be expected to object to having a transfer station in their neighbourhood (even if the transfer station was constructed before there were any houses in the vicinity). Public opposition to open transfer stations is another reason why they are located away from urban areas. The cost of fully enclosing a large transfer station would be very high.
- Compaction type transfer stations in particular are very costly and have high energy costs. There is no reason for compacting the wastes if economical loads can be carried without compaction.

Note size of trailers, presence of spare trailer, and overhang to ensure waste does not fall between wall and trailer. For short-haul distances (up to 20 km) tractors with these large trailers are more efficient than trucks.

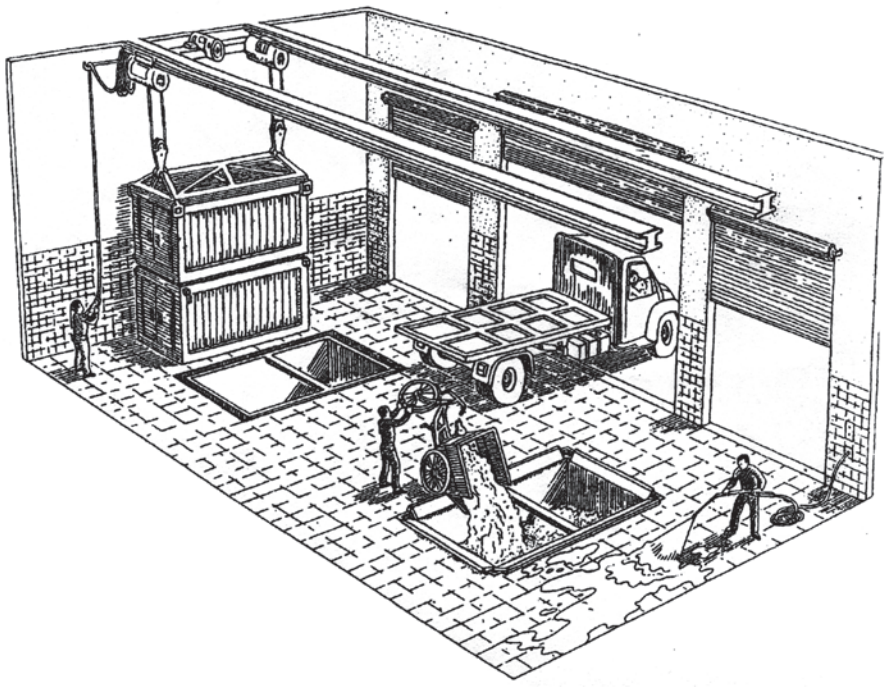
Photo 8.2 Split-level transfer station

8.2.4 Pit and hoist type small transfer stations (STS)

It used to be thought that transfer stations require a lot of space and have problems with noise, litter and odours. As a result they were invariably located away from residential and business areas, some distance from where the wastes are generated, resulting in high collection costs. However a system which evolved originally in China and was then developed further when it was introduced into other countries (including Vietnam [Box 8.2] and Egypt) has changed this thinking. Now *small transfer stations* (STS, Figure 8.1 and Photos 8.3) can be located close to where the wastes are generated and even incorporated into the ground floors of city centre high-rise buildings. This new approach uses multiple, small *city centre* transfer stations in place of one or two larger *out-of-town* transfer stations. One Chinese city, for example, with a population of around 2.5 million, has more than 130 small transfer stations. As a result the distances that the primary collection vehicles have to travel is greatly reduced, and smaller, more economical primary collection vehicles become much more cost-effective than larger primary vehicles bringing their loads for long distances.

The STS works on the following principles:

- An overhead electric hoist deposits large open-top containers into a pit (or pits) in the ground so that the top of the container is at ground level.
- Collection vehicles of all types can tip their loads directly into the containers, without the need for manual handling or special high-tipping mechanisms.
- The capacity of the container is matched to the carrying capacity of the secondary transport trucks, with some spare capacity so that full loads can always be achieved. Containers may have capacities of up to 30 m^3 or more, depending on the waste density and the type of transfer truck used. Typical developing country waste densities allow loads of up to 15 tons per container on a 6 x 4 truck chassis without any compaction.
- Weigh cells at the bottom of the pit determine the weight of the wastes in the container so that the containers can be filled to their maximum load capacity without overloading the trucks. Each container load thus uses 100% of each truck's optimum capacity, reducing the number of loads to the disposal site and increasing truck life.
- The electronic weigh cells at the bottom of the pits can also be used for recording the loads from each primary collection vehicle, thus enabling monitoring of collection operations, a payment-by-weight system for the collection and increasing collection vehicle efficiencies.



Small transfer stations like this are efficient and hygienic. They can be located close to where the wastes are produced to reduce primary collection costs. In the diagram, the containers that would be stored in the right foreground have been removed so that the layout of the transfer station can be clearly seen. The plan dimensions are 16 m x 8 m.

Figure 8.1 Double pit transfer station

- There is space alongside each pit for storing empty or full containers of wastes, stacked up to three high. This space allows a double pit transfer station to store up to ten container loads, (including the containers in the pits and the containers on the two secondary transport [transfer] vehicles). The storage capacity is therefore typically between 100 tons and 150 tons of wastes, depending on the capacity of the trucks and containers used. The hoist is able to lift a full container out of a pit and stack two or three containers beside the pit, without the need of a vehicle.
- The hoist is also used to lift the containers onto the secondary transport trucks. Each truck is fitted with a simple and lightweight skeleton tipping frame onto which the container is lowered using the hoist, so there is no need for a heavy and costly container pickup mechanism. The container is attached to the truck by conventional twist locks which are widely used for handling shipping containers. A hydraulic cylinder attached to the tipping frame tips the container to unload it at the landfill or treatment plant. Thus the load capacity of each truck is around 3,000 kg more than for a hooklift truck.
- The space requirement for this type of transfer station is very small, typically around 20 m by 10 m for a double pit system and 12 m by 8 m for a single pit system. This means that the transfer station can be located on a small site close to where the collection takes place, resulting in short collection haul distances and increased primary collection vehicle efficiency.
- In China it is common to see these transfer stations built into the bottom two floors of high rise apartment buildings, or the space above the transfer station is used for housing, offices, etc.
- The practice in China is to wash the transfer station each day with a high pressure water hose, all wastewater draining into the pits from where it is pumped away to a sewer. Thus there are no smells, insects or rodents with this system.
- This transfer system is not expensive. In Egypt, for example, a double-pit transfer station of this type, with a storage capacity of 100 tons of wastes, was built in 2005 for a total construction cost of US$ 105,000, and a 50 tons/day single-pit transfer station cost US$ 55,000 (also in 2005). The location of the transfer station in the city centre or in residential areas can greatly reduce primary collection costs.

This type of transfer station is very appropriate in congested urban areas where the best means of primary collection is to use handcarts, tricycles, animal carts or small motorised vehicles with a limited range. These

a) In residential block in urban setting in China

b) Low-cost superstructure

c) Container on specially designed tipping transport vehicle. Container capacity to suit waste density and truck load rating.

d) Pit for receiving container; note tiled surfaces, drain and weigh cells in corners

e) Container being lowered into pit

f) Stacking full or empty containers beside pit

Photos 8.3 Small transfer station

Box 8.2

Small transfer stations in Vietnam

A hoist and pit transfer station system was introduced into one area of Ho Chi Minh City and showed dramatic cost savings with increased earnings for the collectors, who, using tricycles as before, were now able to collect two loads each day instead of the one load that they had collected before, when they were obliged to wait for the truck at the rendezvous point. The traffic congestion and unsightly mess created by spillage at the rendezvous points has been avoided. The hoist and pit system has now been expanded into other areas and will eventually replace the rendezvous system completely.

transfer stations can be located in crowded urban areas so that the required range for the primary collection vehicles is suitable for carts and tricycles. Experience in China has shown that there is no problem of smell or littering. City officials and residents' representatives in other countries may not be willing to locate a solid waste facility in the middle of a congested area, so it may be necessary to organise study visits to China or Vietnam so that they can see for themselves that there is no nuisance for the neighbours. The system of loading and secondary transport is economical and robust. The need to construct a permanent structure may seem to be a disadvantage, especially to those who are concerned with only short-term measures, but the upper floors of the building can be rented out or used as offices, and if a different system that does not require the transfer station is introduced later, the ground floor could easily be converted for other purposes, such as shops.

This system of waste collection is not considered to be the best for every case – for example if trucks can collect waste from the point of generation and transport it easily to a nearby disposal site, there is no need of a transfer station of any kind. However, the significant advantages of this system recommend it for careful consideration in congested cities.

8.2.5 Container-to-container transfer systems

A system which is being introduced into smaller towns in the Lake Victoria region of East Africa is a three-stage system that uses small two-wheeled tractors for primary collection, and standard agricultural tractors with specially designed trailers (Figure 7.32) and containers. This system has been described in Box 5.3. The low-cost tractors and special trailers will be able to provide a flexible waste collection and transport system to suit all the different requirements of the towns at only a fraction of the capital and operating costs of a truck system.

8.2.6 General comments about recycling at transfer stations

The separation of recyclable material from mixed waste should be done as early as possible along the solid waste management chain, in order to minimise the degree of contamination of recyclables. Segregation at the source provides recyclables that have the least degree of contamination, but a concerted programme of public education is needed before significant quantities of source-segregated recyclables are available. Primary collectors often sort out recyclable materials during collection. It follows that if recyclable materials are not recovered in these ways, it is better to sort wastes for recycling at a transfer station than at a disposal site The locations of transfer stations are also likely to be more suitable than landfills for the people who do the sorting, and are also probably closer to the dealers who will buy the separated materials. Sorting at a transfer station also allows waste to be sorted before further mixing takes place (perhaps, for example, allowing clean paper waste from a commercial centre to be kept separate from wet waste from a fish and vegetable market), and it also results in less material being transported to the landfill.

However, there are some negative aspects associated with sorting at transfer stations. More space must be provided, both for sorting the waste and for storing the reclaimed recyclables. The actual transfer operation must be in two stages, adding to operation costs. The management of the site becomes more complex, and it is more difficult to keep the site clean.

There are various options for the method of sorting. At composting plants and formal sector waste recovery facilities it is common to provide a picking belt – a continuous moving belt having a width of up to one metre – which carries the waste past a number of pickers who each lift particular materials off and put them into a container or drop them down a chute. This is often followed by a magnet for collecting items containing iron and steel. The moving components require maintenance and the depth of the waste on the belt must be controlled so that no recyclables are buried under other waste. This needs reception storage and careful operation when the loads are coming in as pulses rather than at uniform time intervals.

The other extreme is to sort waste on the ground. This is cheap, but not sanitary, since the sorters are likely to be sitting in the waste. An intermediate option is to put the waste on tables, which may be sloping or in steps, so that the waste is pushed along from one end to the other, recyclables being removed in the process.

Often too little consideration is given to the organisational and motivational aspects of such sorting arrangements. If the sorting workers are paid a salary that is independent of how much material they recover, they may make little effort to remove as much as they can. If individuals are allowed to keep and sell what they recover, there will be great interest in loads from hotels and wealthy residential areas, but no-one will be interested to sort through less valuable waste from slum areas. For the same reason, all the sorting workers will want to work at the upstream end of the belt or table, rather than at the downstream end, where the waste has already been picked over by their colleagues. It may be possible to overcome some of these problems if the pickers can organise themselves into teams of six to ten people, and divide the total earnings of the team equally or according to the number of hours worked.

The incorporation of sorting into the operations at a transfer station requires that the site is bigger than it would otherwise need to be, and it probably also makes the site less tidy and more polluting. For these reasons it would need to be located further from residential areas, so that the distance that is covered by primary collection vehicles is more, thereby adding to the collection costs. These disadvantages make at-source segregation and sorting by primary collectors seem more attractive. This issue shows the importance of integrated planning – looking at all stages, considering all stakeholders and including all impacts (financial, operational, economic, health and environment etc.).

8.3 BULK TRANSPORTATION

In situations in which treatment facilities and disposal sites are at a considerable distance from collection areas, it is cost-effective to transfer the waste from the primary collection vehicles to much larger secondary transport vehicles, often called bulk transport vehicles because of their large capacities. These large vehicles can be classified into six groups.

- Agricultural tractors can pull large trailers, but their range is restricted for reasons of economy, because of their relatively slow speed. In one city in Egypt however, a 65 hp tractor pulls 20 m^3 transfer trailers for distances in excess of 20 km (Photo 8.2) and this has proved to be an economic system.
- Large trucks are fitted with open bodies that are large enough to carry the maximum legal weight of waste. Sometimes three-axle and four-axle chassis are used, but in most cases the use of these heavier chassis is probably not justified because the density of the waste is unlikely to be high enough to form a load close to the legal payload, and the extra operational costs of the larger chassis, particularly in terms of tyre replacements, may make them uneconomical.
- The carrying capacity of a truck can be increased by pulling a trailer behind the truck. The trailer could be loaded at a transfer station in the same way as the truck. The truck could be adapted so that its hydraulic system can operate a tipping mechanism on the trailer, but unless the truck has a side-tipping system (which is not recommended for use on soft landfill sites) the trailer must still be detached to enable the truck to tip its own load. Alternatively, the trailer could be uncoupled from the truck at the entrance to the landfill and connected up to a tractor that can pull it to the working area of the landfill and operate the tipping mechanism using its own hydraulic system. (It might be necessary to uncouple the trailer from the truck for another reason also – because the truck would otherwise not be able to pull the trailer on the waste without slipping.) Some landfill sites have tipping platforms for unloading trucks and trailers that do not have their own tipping systems, but this arrangement makes the operation of the landfill more complicated.
- Hooklift trucks (Section 7.9.3) are very suitable for taking waste from transfer stations to disposal sites. Containers can be left at the transfer station for loading while the truck takes a full container to the landfill, so the truck spends little time loading and unloading, allowing high productivities to be achieved. Open-top containers can be loaded from above (at a split level transfer station or by a wheeled loader), and the first items to be loaded can be brought into the container through the rear doors. Enclosed containers are loaded by static compactor machines that take waste that has been dumped into a hopper and force it into the container. A modification of this system fills containers and places them on racks from which they can be collected by trucks that do not have hooklift mechanisms but collect the containers by reversing under them when they are supported on a frame. In all cases the containers are emptied by tipping. The container capacity is restricted by the weight of the hooklift mechanism and the additional weight of the special hooklift container.
- A truck system used with the small transfer station (STS) described in Section 8.2.5 has a simple skeleton tipping frame and a much lighter container, enabling the truck to carry up to 3,000 kg extra each trip. The

container is lifted onto and off the truck by an electric hoist at the transfer station (Photo 8.3.d).

- Large compactor trucks may be used for long haulage distances (but the disadvantages of compactor trucks listed in Section 7.8.1 must be carefully considered before this type of vehicle is selected). It may be appropriate for small, non-compaction vehicles to take their loads to transfer stations and for big compactor trucks to go directly to the landfill. It must be remembered that compactor trucks have heavy loading and compaction mechanisms that are not required for long distance transport.
- Articulated trucks (semi-trailers – Photos 8.1 and 8.4) are also used for long distance bulk transport because of their very large capacity. Another advantage is that a trailer can be left at a transfer station for loading while the tractor unit[35] and driver are going to the disposal site with another trailer that has already been loaded. In this way the productivity of the tractor unit is very high. Section A5.5.2 of Annex A5 mentions some particular problems experienced by articulated trucks when operating on landfills (Photo 8.4). Wastes may be tipped in from above if the top of the trailer body is open, in which case the load should be covered before the vehicle moves off. Alternatively the trailer body may be loaded by compacting the waste in from the rear if the body is strong enough to withstand the forces and abrasion.

  Long trailers should not be emptied by tipping, as they are likely to turn over sideways on soft ground.

  Some trailers are fitted with ejector plates operated by very long multistage hydraulic rams. These rams are vulnerable to damage and expensive to replace, and the ejector plate may cause extra stresses on the body of the trailer unit and cause the waste to lift and damage the tarpaulin cover (in the case of open-topped trailers) unless it is removed before unloading. Others are fitted with either conveyor belts or "walking floors"[36] which move the waste into the trailer unit for loading and out for unloading.

In selecting the type of vehicle that is to be used for bulk secondary transport, it is important to consider most of the factors that were listed at the beginning of this chapter, so that the service is both economical and reliable.

Railway and river transport are also used for long distance transporting of waste. In such cases the collection chain may have three or four stages, because the waste needs to be transferred back onto a truck at the end of the river or railway journey, so that it can be taken to the operational part of the landfill. To simplify these transfers the waste is put into containers at the first transfer point and kept in the same containers until it is tipped out at the landfill. Large *off road* dumper trucks can be adapted for handling containers of waste on landfill sites, although they are costly and add an extra process into the transport chain. The may be used for handling containers that are brought to the landfill by articulated trucks, as well as by river and rail.

35. A tractor unit should not be confused with an agricultural tractor. The type of vehicle that is referred to here has a cab (which is the same as the cab of a large truck) mounted on short but strong chassis with equipment for attaching the trailer unit and connections to operate the electrics and brakes of the trailer unit.

36. A walking floor has oscillating beams which move the waste. They lift to support the waste and move it a short distance – typically 10 cm – before lowering to return to their starting position while fixed beams take the weight of the waste between each cycle.

Photo 8.4 Tracked loader helping an empty articulated truck to move off the waste

Summary points

- Two-stage collection with transfer adds to the complexity of the collection system but can bring particular advantages.
- Poorly conceived transfer arrangements can lead to inefficiencies and scattered waste.
- Direct transfer into large containers or trailers reduces environmental problems.
- Small transfer stations within buildings in congested urban areas enable efficient and clean transfer, as well as cost-effective primary collection and secondary transport, but city authorities may be reluctant to locate them in busy areas, even though they are widely used in this way in China.
- A number of small transfer stations will generally be more cost-effective than a single large one.

OPERATION AND MAINTENANCE OF COLLECTION VEHICLES

9

9.1 INTRODUCTION

The operation and maintenance of the refuse collection and landfill equipment can form a large part of any local authority's budget. In the past the focus of projects involving international assistance was only on providing equipment and construction of facilities, but increasingly such projects are including capacity building and assistance with the early stages of operations. This is warmly welcomed because operation and maintenance are often in need of real support, and familiarity with problems relating to the operations phase helps consultants and decision-makers to make more sustainable recommendations in the future. Private sector operators with any experience are very familiar with the impacts of operation and maintenance on vehicle choice and allocation of resources, and are careful to include feedback from operations experience in their decisions, because they know that their reputation and profit depends on this.

Unfortunately the situation is less satisfactory in the government sector. Local and national administrations must give more importance to operations and maintenance. The selection of vehicles at either national or local level is often made without reference to operations managers and maintenance engineers. Insufficient attention is given to developing the capacities of the departments concerned with operation and maintenance. Financial structures and procedures are often not suitable for the demands of maintenance. There is often a division in the control and responsibility for all expenditure components. Examples are the payment of salaries from central funds and other operating expenses from local revenues, and the provision of capital or equipment by the national government. This fragmentation of responsibilities leads to inefficient systems. Inadequate financial responsibility for maintenance managers, insufficient resources for maintenance, and delays in financial allocations for maintenance all result in increased costs and inferior services.

Much can be learned from experience. Collection operations and maintenance should be observed and monitored. Work study (Annex A1) has two aspects:

- **Method study** – which observes how the work is done and suggests improvements in working methods that maximise efficiency by simplifying or reducing inputs, reduce interference between workers, and avoid risks of injury or infection. Much can be learned from observation, and the suggestions of drivers and labourers, as well as foreman, should be listened to carefully.
- **Work measurement** – which involves collecting data on times, numbers, weights and distances so that performances can be compared, unit costs and productivities quantified, and the benefits of possible improvements estimated. The results of measurement and calculation form a good basis for management decisions, so that costs can be reduced and coverage increased. In general, solid waste management suffers from a serious lack of objective data on operations and maintenance performance.

A proper preventive maintenance programme can greatly extend the life of equipment and reduce downtime, resulting in a reduction in the amount of equipment needed as well as an improved level of service. Too often, it is found that responsibility for the operation and maintenance is included among the many functions of an administrator who has little understanding of the technical aspects of this activity and a financial controller who is usually concerned with short-term financial issues. If the official who allocates funding for operational expenses does not understand the importance of maintenance, (s)he may not understand the consequences of the withholding of finance for the purchase of spare parts for just a short period – such as two weeks. The result of such delays in agreeing financial allocations may be the eventual need for large capital amounts to replace equipment which has not been adequately maintained or to purchase additional standby equipment that is needed only because of the long delays in returning vehicles to use after breakdowns.

The details of operation and maintenance vary considerably, influenced by many factors, such as population served, level of service, geography and layout, types of vehicles, involvement of the private sector and organisational structure. This chapter does not try to cover all aspects of operation and maintenance. Rather, it discusses aspects of the planning of collection routes, communication, monitoring of performance, and preventive maintenance. Some points relating to operations can also be found in Chapter 12. A typical preventive maintenance programme is described in Annex A2

9.2 PLANNING COLLECTION ROUTES

Careful planning of the routes followed by collection vehicle can speed up collection and increase vehicle and labour efficiency. Route planning involves a careful study of each collection area in order to maximize each vehicle's daily collection capacity. Simple rules for route planning include:

- Vehicle routes should minimise the distances travelled for each collection load and maximise the loads. The first route each day should start close to the vehicle depot and finish with a fully loaded vehicle as close as possible to the transfer point, treatment plant or disposal site. Subsequent routes should start and finish close to the disposal point.
- Vehicle routes should take into account traffic conditions in different parts of the city at different times of the day and particular traffic problems so as, for example, to avoid passing schools at the start and finish of the school day. It may be necessary to collect in city centre areas at night and for block systems in residential areas to operate at times when the residents are at home.
- Vehicle routes must take into account any local legislation such as, for example, weight limits on roads or bridges. They should also take into account street widths and congestion caused by parked cars or trucks at different times of the day.
- Routes should as far as possible avoid turns across traffic – in countries which drive on the left they should avoid right hand turns and vice versa. Difficult "U" turns should be avoided.
- The designing of collection routes for vehicles requires an intelligent common-sense approach rather than high technology. Writing computer programs to determine optimum routes is an interesting academic challenge, and there are many such programs in existence. However, it must be remembered that the output of a computer is only as good as the input data. If the program does not consider effectively issues such as traffic problems, difficult turns, and delays at places where loading is difficult, the output is unlikely to be helpful. Drivers may have their own reasons for preferring a particular route. For example they may wish to pass a particular café at their tea break time or pass a recycling depot where they can sell recyclable materials they have collected during their round. The manager must decide when to compromise and when to insist on adherence to instructions. Computers may play a part in determining the best routes for collection vehicles, but common-sense, compromise, co-operation, experience and observation are all essential in selecting routes that minimise costs and divide the work fairly between the crews. If the collection areas can be divided in a fair way so that the time required for each area is approximately the same (this may not mean that each team collects the same weight of waste since differences in travel times, access problems and loading methods must be taken into consideration) it may be sufficient to let the drivers plan the actual routes within the collection areas.
- A work study team should spend time studying the operation of each vehicle from the vehicle cab and noting delays and other inefficiencies before "fine tuning" the vehicle routes and allocations of duties. The purpose of such observations should be explained to the crews to get their support and co-operation.

A redesign of collection routes and collection frequencies in one part of the West Bank of Palestine resulted in fewer complaints and a 20% reduction in collection charges. [El-Hamouz, 2007].

9.3 COMMUNICATION

Communication within a large organisation is a very important issue, and it is even more important when there is an important interface with the general public, as is the case with solid waste collection. Communication with the public is a very important issue which is discussed briefly in Section 12.8.3. Communication within an organisation is important for many reasons, including making the best use of each member of the organisation and developing team spirit. The aspect discussed in this chapter is directing the workforce.

Communication is particularly important in solid waste collection because most of the employees are scattered over a wide area and moving continuously. A collection crew may need to inform its superior regarding a breakdown, an accident, a particular problem (such as a fire in the waste or a damaged container), or a complaint or observation that needs urgent attention. Collection crews may need to be informed regarding extra loads that need to be picked up, traffic congestion that could be avoided and assistance that may be needed by another crew because of breakdown or some other reason. It may also be necessary to ascertain the location of a particular collection crew.

There are three levels of communication:

a) The cheapest and simplest is to instruct the workforce when they sign on at the muster station or district office at the beginning of the shift and to ask for information at the end of the shift, when they sign out. If a collection vehicle passes an operations control room or landfill gatehouse on its route, a message can be transferred from this location.
b) The next level is to equip supervisors with a means of communication – mobile phone or two-way radio – so that they can pass on any message to the employees that they supervise (after first locating them).
c) The third level is to equip each team with a means of communication. It is desirable that each team in a refuse collection truck has its own mobile phone or two-way radio set, but it is not necessary for collectors using slow, local vehicles, such as handcarts nor for street sweepers, because it should be possible for their foreman or supervisor to locate them reasonably quickly. Since cellular telephone networks are almost universally available and the costs of mobile telephone charges are reducing, there is no reason why each vehicle should not be equipped with a mobile phone, perhaps limited to local calls only. Two-way radio can also be used but this is more costly.

Some additional comments on communications equipment can be found in Section 12.8.4.

9.4 MONITORING

As with planning (Section 10.1) monitoring[37] of performance seems to be neglected by most municipal managers who are responsible for waste collection. The reasons for attaching little importance to the collection and use of data relating to operations and maintenance performance may be similar to the reasons for avoiding medium-term planning, and include

- lack of time because of the heavy load of administration and the lack of delegation,
- an organisational culture in which assessment of performance is not encouraged, and
- a lack of knowledge, understanding and confidence.

Monitoring involves three stages:

a) The collection of data – Some data should be collected on a routine basis, such as weights of waste taken to the disposal site (if there is a weighbridge), the list of vehicles which are operational each day, the reasons why the other vehicles are not operational, trip times, distances covered by each vehicle, number of premises or containers served, expenditures under various headings and numbers of employees (casual and permanent).

Other data may be collected from time to time, such as random weights of loads (if an external weighbridge must be used), work study measurements of operations, and measurements of waste density. Care must be taken to ensure that these measurements are representative of the normal situation. For example, when their rate of working is being observed and measured, some labourers might work harder than normal to gain the approval of their supervisors, and others might work slower because they know that future allocations of work may be decided on the basis of the measurements, and they believe they will be asked to do less work if they work slowly when being observed. Judgement is needed to assess whether the rate of working is reasonable. Vehicles may be loaded with more waste when the loading crew know that the truck will be weighed, so it is preferable to tell the driver to go to the weighbridge only after loading is completed.

b) Calculating with the data – The mathematics is basic, but it is important to be methodical and careful in performing calculations to ensure that all relevant data are used in the correct way. For example, when calculating workforce costs it is important to include all payments made to the employees, making allowance for leave, including social insurance payments, and adding overheads, such as the cost of supervision and administration. If costs and outputs are calculated on the basis of one day, there can be difficulties in making allowance for weekends, so it is better to calculate unit collection costs on the basis of a longer period, such as a week or a month. Box 9.1 gives examples of calculated results from Gaza [Scheu, 2003].

There are advantages in using spreadsheets for calculations, because if they are carefully developed and certain cells are protected so that they cannot be changed accidentally, there is less chance of making arithmetic errors. Spreadsheets also facilitate repeated calculations, so it is easy to investigate the effect of variations in a variable (either to show the impact of an operational change or to investigate how errors in one item of data might affect the final result).

37. *Monitoring is the regular collection, use and review of data that indicate inputs and outputs.*

c) Using the results. – There should always be a clear purpose in every data collection exercise. Monitoring information may be used in a number of ways, including:

- comparison of current performance with previous performance, to indicate the effects of changes in management approach or capacity building;
- comparison of performance in two locations (after checking that the data are collected and the calculations performed in the same way in each location), to indicate if improvements can be expected;
- comparing the performance of loading crews or the work input required by different collection routes, by rotating the crews among the routes and measuring their performance;
- comparing drivers (in the case in which one driver usually drives the same vehicle) to see which drivers need more training (because of, for example, excessive wear on the clutches or tyres of the vehicles that they drive);
- monitoring distances covered for scheduling maintenance (Section 9.5) and, in conjunction with reported fuel consumption, to control the theft of fuel;
- anticipating the effects of possible changes in management or allocation of funds, such as putting more resources into preventive maintenance (Section 9.5);
- comparing the reliability of different chassis or bodies, in terms of their availabilities[38] (Box 9.2 shows availabilities of private and public sector fleets);
- estimating the costs of alternative collection systems, such as changing the frequency of collection, the size of the crew with each vehicle, or the type or size of vehicle. In the case of an investigation regarding the impact of a change of vehicle, it may be possible to collect some data from another city where these vehicles are used or to investigate the effect in some other way. For example, it is possible to investigate the effect of loading height by constructing a barrier of the appropriate height and passing waste over the barrier. It may be possible to hire a vehicle for a short time to measure costs and productivity;
- comparing actual productivities and unit costs with those expected when the system was designed,
- estimating the economic life of a particular type of vehicle.

It is useful to consider how to present the results. It is often useful to show results on a graph, so that trends can

38. Availability is the percentage of time that a vehicle is available for duty. It can also be the number of a particular type of vehicle that is available for duty, as a percentage of the total number of that type of vehicle. A vehicle is said to be available for duty even if it is not required and is a standby. If a vehicle is not available is it said to be down; availability = 100 – % downtime.

Box 9.1 Example

Performance results for crane-tipper system in Gaza

In total 12 collection vehicles were being operated on a scheduled basis to serve communities with a total population of about 240,000. This is equivalent to one truck per 20,000 people. Two additional trucks and crews were on standby. Each truck emptied about 145 communal containers, each with a capacity of 1.0 m³. Containers in urban areas are emptied daily and in rural areas at least three times per week. The total number of containers is about 1,750 which is equivalent to about 140 persons per container. Average distance covered per trip 35 km.

The weighbridge at the landfill site (Photo 9.1) provides the data required for performance monitoring of collection vehicles and crews. Records at the weighbridge include:

Date | Time | *Truck No.* | *Area served* | *Driver*
Gross weight | Tare weight | Vehicle load

Trucks pass over the weighbridge when entering the landfill site and only the three codes for the items shown in italics are entered by staff member at the gate house. The remaining data are stored or calculated electronically by the system. This provides a reliable and complete set of data for further analysis.

Important performance indicators calculated using this information are:

- **Collection efficiency of vehicles 2.6 tons per hour** (average load 7.70 tons, 2.05 trips per shift, 6.0 hours per shift).
- **Labour productivity 1.3 tons per crew member per hour** (considering a crew of one driver plus one additional assistant).
- **Vehicle utilization about 84%** (considering that 12 trucks plus 2 standby vehicles, equivalent to 12/14 = 86%, have been sufficient to perform the services and that 2% of the shifts were cancelled in 1998).

[Scheu, 2000]

Photo 9.1 Weighbridge for collecting operational data

Box 9.2 Example

Vehicle availabilities in a capital city in Africa

The following data were collected for different types of vehicles for both the public and private sectors.

	Public sector			Private sector		
	Number owned	Operational		Number owned	Operational	
		Number	Percent		Number	percent
Flat bed trucks	4	4	100	12	10	83
Tipper trucks	8	2	25	48	32	67
Hook lift	2	2	100	1	1	100
Tractors	3	2	67	1	1	100
Compactor trucks	17	5	29	9	8	89
Side loader trucks	2	2	100			
Total	**36**	**17**	**47**	**71**	**52**	**73**

Comments

No data are given regarding the ages of the vehicles. Clearly it is more difficult to keep a truck that is 15 years old in operational condition, in comparison with a truck that is new. If the ages of the vehicles are similar, this table illustrates two trends:

(i) It is more difficult to keep complex vehicles such as compactor trucks in operational condition

(ii) The private sector is generally more successful in keeping its fleet operational than the public sector.

Based on information in Imam (2007)

easily be seen, or links between two aspects can be demonstrated. Information may be summarised so that it can be shown at a glance on one sheet[39]. The total cost savings that are anticipated to accrue from a proposed change may be very persuasive.

9.5 PREVENTIVE MAINTENANCE

Preventive maintenance is an essential part of the operation of any collection equipment to ensure that the maximum equipment life is combined with minimum out-of-service times (downtime) and that the equipment is at all times operating at its maximum capacity.

A clear distinction must be made between preventive maintenance – which is carried out to a defined and disciplined programme – and crisis (or breakdown) maintenance which is only carried out when a fault develops. An important aspect of a *planned preventive maintenance* programme is to anticipate faults and prevent a minor problem (such as a loose bolt for example) from developing into a serious failure which may require costly repairs or spare parts. A problem such as an oil leak, a blocked filter or a leaking air intake hose in itself is a very minor problem but if it is not attended to it may result in a complete engine, transmission or hydraulic failure.

A lack of adequate servicing is probably the single most serious factor affecting the quality and reliability of any service that is provided by a municipality. It is not uncommon to visit a municipal vehicle depot and find that a half or even more of the equipment is out of service because of simple problems which could have been avoided. Often, many of the vehicles are awaiting spare parts which are not available locally and have to be imported from overseas. Even if the parts are available locally, there can be unnecessary delays in making even simple repairs, as illustrated in Box 9.3. Very often, equipment is idle, awaiting the funds necessary to purchase parts which have not been budgeted for in the annual budget. One of the benefits of a preventive maintenance programme is that it gives advance notice of any requirement for spare parts so that the vehicles are not kept waiting or out of service while the parts are being obtained.

Good preventive maintenance starts with the selection and specification of the vehicles and equipment. The vehicles should be well suited to the local conditions and the work to be done, and be of makes and types for which spare parts are readily available. Simplicity is often associated with reliability. If vehicles are not selected with maintenance in mind, they are likely to spend much of their lives in the workshop awaiting repair.

A planned preventive maintenance programme will not only keep existing equipment operating at its maximum efficiency but will also provide the information to the financial planners which will enable them to include accurate forecasts of required expenditures for parts and

39. *See, for example, Appendix DD-1.1 in [Coad, 1997]*

Box 9.3 Example

Problems in procuring spare parts

Some years ago one of the authors was involved in an emergency clean-up of an East African city. The city was generating more than 1,000 tons of wastes per day and had a fleet of 28 tipping trucks, but only five of these were still operating and the city authorities were collecting only around 30 tons of wastes (3%) of the wastes generated each day. The city was suffering from outbreaks of cholera and typhus, believed to be caused by the heaps of uncollected wastes.

The city offices are in the centre of the city, the municipal workshops are about 8 km to the north and the central municipal stores are about 5 km to the west of the offices and some distance from the commercial area. There was a very small store at the workshops for oil filters, etc, but most parts, if they were available, were kept at the central store about 8 km from the workshops. There was no telephone at the workshops and no small vehicle, (motorcycle or light van) available for the use of either the workshop manager or the central stores manager.

A problem arose when one of the five operational trucks broke down and required a spare track rod end, costing perhaps $50. The procedure for obtaining a replacement part was as follows:

- The mechanic went to the workshop manager, showed him the faulty part and requested an order for the new part. The mechanic then went to the workshop stores with the order and was told that they did not have a part in stock. The workshop manager then wrote out a requisition to the central stores for the part.
- As there was no transport at the workshop stores the workshop manager requisitioned one of the four remaining refuse trucks to take the order to the central stores. The collection service was now down to only three trucks and two teams of collection crews were idle.
- To prevent pilfering of fuel, the refuse trucks are issued with only enough fuel for each day's work. The truck driver therefore had to get a fuel requisition from the workshop manager and drive 1 km to the fuel station to purchase this fuel before returning to pick up the mechanic to deliver the requisition to the central stores. The central stores did not have the part in stock but undertook to obtain one from a local supplier.
- Under the City Council regulations, the central stores manager had to obtain three competitive tenders for the part required. However, before requesting these tenders he had to obtain the signature of the financial controller at the municipal offices on the "request to tender" orders. The central stores manager had no transport so he requisitioned the refuse truck which had brought the original requisition from the workshops. At the Municipal offices he was told to come back the next day to pick up the signed requests.
- The following day he collected the requests by taxi and drove to the three suppliers specified. Each of these suppliers told him to come back the next day. (The delay was so that the three suppliers could agree amongst themselves what price they would each charge and which of them on that occasion would get the order.) None of the suppliers would supply the parts without being paid in advance because of the Municipality's poor payment record. Each of the three suppliers made out a pro-forma invoice for the different amounts that they had agreed amongst themselves.
- The following day the central stores manager hired a taxi to collect the three pro-forma invoices and bring them to the municipal offices where he was told that the financial controller "only signs cheques on Thursdays" and to come back the following Friday to collect the cheque.
- On the following Friday the central stores manager took a taxi to the municipal offices and collected the cheque for the agreed supplier. He delivered this cheque and was told to come back the following day after the cheque had been cleared.
- The following day he took a taxi to the supplier, collected the part and brought it back to the central stores.
- In the meantime, someone from the workshop had visited the central stores on several occasions (as they did not have a telephone) to ask if the part had come in, each time travelling there and back in a refuse truck because they did not have any other transportation.
- The central stores did not have any means of contacting the workshop and so the part remained in the stores for several days until at last a truck from the workshop truck arrived to collect it.
- After being out of service for nearly three weeks the truck was repaired and operational within two or three hours.

Imagine what happens if the part must be ordered from overseas.

servicing in their annual budgets, and to make informed decisions concerning future vehicle replacements.

An important impact of any preventive maintenance programme is that it changes the institutional culture of a municipal administration. Breakdowns are no longer seen as random events that cannot be foreseen and are outside anyone's control. Preventive maintenance imposes on municipal officials at all levels, from the drivers and the storeman to the workshop manager, a sense of accountability for breakdowns and delays in making repairs after a breakdown. Delays may also be due to a lack of funds for purchasing essential parts so the accountant or financial controller may be accountable. The costs to the municipality of having vehicles out of service can be seen, and responsibility can be allocated. This can be an effective incentive for allocating sufficient funds to the maintenance department.

The system is designed so that each check or servicing activity that is carried out is a confirmation that the previous checks have been adequately performed.

- The weekly servicing checks by a junior mechanic show if any of the drivers have not been performing their daily checks adequately (for example, if the oil level in a vehicle is low its drivers has not been checking it regularly).

- The monthly servicing check by a senior mechanic reveals any inadequacy in the weekly checks (for example if more than one or two loose bolts are found this will indicate that they are not being adequately checked or tightened during the weekly checks).
- The six monthly check shows whether the monthly checks have been adequately carried out.

In this way each person is checking the performance of the previous and more junior person.

A measure of the success of a preventive maintenance programme is *availability*, which is the proportion of the time that a vehicle is ready for service (even if it is on standby and not actually being used). It can also be taken to mean the number of vehicles (perhaps of a particular type) that are ready for service on any particular day, divided by the total number of vehicles in the current fleet. By plotting a graph each month of the availability, a manager can see at a glance an indication of the condition of the vehicles and whether the maintenance programme is improving or weakening. Availability levels can be used to show the number of standby vehicles that are needed (for each type of vehicle) and which types of vehicle are more reliable.

Annex A2 sets out a typical preventive maintenance programme for a municipal workshop with a large fleet of trucks. Each of the functions is an essential part of the programme, even for a small vehicle fleet. Where there are not many vehicles, some functions and data sheets may be combined because of the smaller number of staff.

Summary points

- Efficient operation and maintenance depend on comprehensive and accurate data collection and good planning.
- There are many computer programs for planning vehicle routes, but in this connection the value of common sense and local knowledge should not be underestimated.
- Modern communication tools can enable services to be more reliable and more efficient.
- Preventive maintenance enables early discovery of mechanical problems so that expenditure can be saved, downtime minimised and maintenance work planned.
- Preventive maintenance is often associated with a change of culture in vehicle management.

10 FINANCIAL ASPECTS OF SOLID WASTE MANAGEMENT

10.1 INTRODUCTION

If a system is to be fully sustainable it is essential that all long-term financial costs as well as short-term operating costs are taken into account and that procedures are in place for obtaining regular finance to meet these costs. Otherwise a collection system may be set up which will work well for a short period and then collapse as operating funds (for labour, fuel and maintenance) run out and the equipment becomes obsolete. Local authorities usually have annual budgets. Accurate cost forecasting is essential for the preparation of these budgets to set up adequate funding so that funds do not run out towards the end of each budgeting period.

If the collected waste is simply dumped in an open dump, the costs of waste disposal are very small in comparison with collection. If solid wastes are disposed of in an environmentally acceptable way in a sanitary landfill, the operation costs become much more, requiring a sizable increase in the solid waste management budget. A new sanitary landfill which is located at a greater distance from the city than the dump it replaces will also cause an increase in transport costs, and it is important that the effects of travel distances and times on collection costs are known and considered when making any decisions regarding a landfill location. Disposal costs are only briefly covered in this publication.

Planning is essential if a system is to be sustainable. Plans must take into account population growth, increases in waste quantities per capita and expanded areas from which waste must be collected. Population growth rates in developing countries are generally high and urban growth rates of up to 10% per annum are not uncommon. In many cities waste collection services are only provided in the commercial and middle- to high-income residential areas with no services to the low-income unplanned or peri-urban areas. As living standards increase with a strengthening economy and as consumer habits change, the amount of wastes generated by each citizen will increase.

Anticipated changes in treatment and disposal measures also demand planning. In many cases the life of existing disposal facilities is limited because improving standards demand better landfills, because urban expansion requires that sites be found further from the urban centre, or because the available space in a landfill will soon be filled. New sites mean new routes and usually longer travel times when transporting the waste to its new destination. Plans can therefore include new types of storage, collection and transportation systems, and additional equipment.

Unfortunately, in many municipal systems there are barriers to effective planning. The most common obstacles to planning are

- **The short time horizons in local government** – Local politicians often concentrate on gaining popular approval in the hope of winning the next election, and so they have little interest in anything that has a long-term impact. Solid waste management plans should be looking at least ten years ahead, but the next election may be less than four years away.
- **The lack of control of capital expenditure** – In many countries, municipal officials have little control over capital expenditure. The timing of the provision and the selection of new waste collection equipment is often determined by regional or national authorities, with little consultation. The separation of capital and operational expenditure (for example, capital expenditure is decided at national level and recurrent expenditure at local level) means that municipal administrations are not able to acquire new equipment in order to minimise total costs, but may be forced to use old, unreliable and inefficient equipment which entails a much greater operational cost or restricts opportunities for revenue collection because only a small part of the urban area can be provided with a waste collection service. Local government is often unable to obtain loans. The private sector has distinct advantages in this area, as will be discussed in Section 11.2.
- **Lack of time, training and encouragement** – Planning is foreign to the culture of many municipal administrations. Senior officials are often responsible for a wide range of activities, and are also responsible for trivial issues as well as important ones. Being fully occupied with details and crises, they have no time for developing new approaches and for planning. Furthermore, they may have had little training in solid waste management, and so lack confidence in forecasting needs and calculating unit costs. Municipal leaders

themselves may have little awareness of planning and therefore provide no encouragement. Although solid waste management is primarily a mechanical engineering function it is common to find that it is under the responsibility of a medical officer or a civil engineer.

The costs of operating any sustainable waste collection system must include all of the costs listed in the next section.

10.2 OPERATING COSTS FOR WASTE COLLECTION

These include expenditure on labour, fuel and maintenance, which must all be included in any annual budget. The funds should be made available weekly to the *cleansing manager* without his having to refer each time to the head of the municipality or the financial controller. Unless these funds are continuously available without any delays it is impossible to run a regular collection service and any system which has been set up will rapidly come to a stop. The operating costs for treatment and disposal can be very significant but have not been included here.

10.2.1 Labour costs

Labour costs include the cost of the vehicle drivers or operators, loaders, street sweepers and any foremen and supervisors directly employed for the collection service. It also includes all the costs directly attributable to the cost of employing the labour, including any housing, food or other allowances, holiday pay, tax or other payments for which the employer is responsible, health insurance, sickness pay and protective clothing.

10.2.2 Energy costs

The main item in this category is the fuel (petrol [gasoline] or diesel) consumed by the collection vehicles and vehicles used by supervisors, managers and others in connection with solid waste management. There may also be spare vehicles, which are on standby or only used part-time and these must also be taken into account. In some cases there may be street sweeping machines and electricity generating sets. The average fuel consumption per hour for any vehicle while it is operating should be multiplied by the average number of hours worked each day. Diesel-powered vehicles are more economical and generally last longer than petrol-powered ones. Payment for electricity must also be included.

10.2.3 Maintenance costs

Maintenance costs include the costs of the labour for servicing and repairing vehicles and equipment and the cost of the parts and materials used including oils, hydraulic fluids, greases, and routine and emergency spare parts. During the first years of a vehicle's life the maintenance costs should be quite small and include only standard service parts such as oils, grease and filters. Higher costs are incurred when tyres and other wearing parts such as brakes, clutches and steering parts need replacing. Later comes the eventual major reconditioning of engines, transmissions, etc. At any stage breakdowns or accidents may occur, requiring expensive parts which are not in the stores and so must be procured with minimal delay.

If there is no prior experience of maintenance expenditures, it may be assumed that, for normal use, the annual maintenance cost of a vehicle or equipment is about 5% of the original cost. However where vehicles are operated on two or more shifts per day, this should be increased to perhaps 8%. As the vehicles and equipment age, these costs will increase.

It is essential for any sustainable system that procedures are in place for carrying stocks of routine service parts and materials and for the fast procurement of unexpected parts without the delays normally caused by local authority financial controls. Delays in the procurement process cause excessive vehicle downtimes, resulting in an unreliable service and the need for extra capital expenditure to buy additional standby vehicles and other equipment.

Annex A2 includes procedures for the stocking of routine service parts and the procurement of emergency parts. It is not unusual to find situations where, because of the lack of spare parts, a very large proportion of a city's fleet of vehicles is out of service awaiting these parts, resulting in the failure of the collection service and insanitary conditions in the city. The authorities then see no alternative but to hire in contractors and costly trucks to sort out the mess.

10.3 FINANCIAL COSTS

Financial costs are the costs associated with owning assets (such as vehicles) but not with operating them. These costs include the *depreciation* of the vehicles, equipment and fixed assets (discussed in Section 10.3.1 below), and the *interest* or *opportunity cost* of the capital used (discussed in Section 10.3.2).

Arrangements for purchasing vehicles and other assets differ from country to country, according to regulations and financial procedures. Sometimes the purchase of vehicles is not the responsibility of local government, but of regional or national government. This initially sounds like an attractive arrangement, relieving local government of these costs, but it also means that local government cannot determine the type of vehicles to be purchased and the timing of these purchases, and so the local administration has little control over the development of the refuse collection service. There may be restrictions on the ability of local government to obtain commercial loans. If the purchase of capital equipment is the responsibility of local government, the head of the municipality and the financial controller must take this into account when preparing annual budgets, otherwise the system will be unsustainable in the long term and will come to a stop when the equipment reaches the end of its economic life, because there will be no money to buy replacements.

10.3.1 Depreciation

Each capital asset (such as a vehicle) has an economic life, after which it is more economical (considering both operating and financial costs) to replace the asset with a new one. As vehicles and equipment get old, the time will come when the operating efficiency decreases and maintenance costs increase to a point when it is more cost-effective to replace the equipment than to continue repairing it. It may, of course, be possible to keep equipment working long past the end of its economic life; however increasing maintenance costs with increased downtime, higher fuel consumption and reduced operating efficiency will mean that this is not cost-effective or sustainable in the long term. Depreciation is a way of converting capital expenditures (made at intervals of more than one year) to annual costs, and can be calculated by dividing the capital cost of an asset by its economic life.

At the end of this economic life, the asset has a residual value – the price that could be obtained by selling it. However it is often found that municipalities are not authorised to sell off obsolete vehicles and equipment, or that the process of obtaining permission to sell them is so long and complicated that local administrations do not even try to sell them. In some cases a vehicle that has been provided as a grant from central government remains the property of central government, even after the end of its economic life, and so local government is not authorised to sell it when it is no longer serviceable or required. The result is that maintenance workshops are cluttered up with obsolete and broken equipment, taking up the space that is needed for servicing and parking the working equipment.

There are differences of opinion as to how depreciation should be handled. Some accountants calculate this loss of value as a percentage of the depreciated value of the asset for the particular year, so that the loss of value of the asset reduces each year and the residual value of the asset continues to tail off indefinitely. However, this approach is not realistic where vehicles are supplied by central government. In such a case a vehicle that has passed its economic life has a zero residual value to the municipality, because it is not possible for the local administration to get rid of unwanted machinery since it still has a theoretical value and is owned by the national government.

It is therefore more practical to assume *straight line* depreciation. This means that the annual depreciation rate is equal to the initial value of the asset divided by its estimated economic life, and is therefore the same each year. At the end of its economic life the asset will have a zero *book* value and the local authority should be entitled to scrap the vehicle, cannibalise it for spare parts, or sell it off and use the funds obtained for enhancing its remaining fleet.

This straight line depreciation can be illustrated by a simple example. A vehicle costing $100,000 with an economic life of seven years has an annual depreciation of 100,000 ÷ 7 = $14,285 and a book residual value as shown in Table 10.1.

An old vehicle always retains some practical residual value even as scrap metal. However, old vehicles and scrap that cannot be sold and occupy valuable space at a workshop or depot are a liability rather than an asset.

There may be government regulations determining the depreciation periods to be used for different types of asset. The actual economic life of an asset may be different from the depreciation period – longer if it is well maintained and shorter if it is used intensively and does not benefit from a good maintenance programme. However, for the purposes of calculating depreciation, defined periods are used. If there are no government regulations defining these periods, the values shown in Table 10.2 can be used.

Depreciation does not include any operating or actual recurrent costs. Depreciation is a simple way of including capital costs in unit costs (such as the cost of collecting one ton of waste). This concept of depreciation does not make any allowance for inflation (the expected increase in the price of the asset during the current asset's economic life), and does not include the interest that would be paid if the asset were financed by a commercial loan from a bank.

The best way of using this concept of depreciation is to regard it as an annual expenditure and pay this sum

Table 10.1 Example of straight line depreciation over seven years

Time	At time of purchase	At the end of year… 1	2	3	4	5	6	7
Residual value ($)	100,000	85,715	71,430	57,145	42,860	28,575	14,285	0

Table 10.2 Depreciated life expectancy for different items

Type of asset	Typical economic life (years)
Fixed assets such as buildings	20
Trucks and other motor vehicles	7
Tractors, bulldozers, loaders, etc	10
Hand tools, bins, handcarts, wheelbarrows, etc	4
Large containers made from mild or ordinary steel	4
Large containers made from special CorTen* steel	8
Animals such as donkeys or horses	5

** Note: CorTen steel is more expensive than mild steel but is more resistant to corrosion (Box 5.1). The extra initial investment in corrosion-resistant steel will result in significant long-term cost savings.*

(if possible corrected for inflation) into an account. By the end of the depreciation period of the asset (a vehicle in this case), the sum of money in the account (plus the interest earned), when added to the income (if any) from the sale of the old vehicle would provide enough to buy a new vehicle of the same kind. In this way the service can continue with the new vehicle. Unfortunately it is not common for local government administrations to build up *sinking funds*[40] in this way. Even if a sinking fund can be established, it is likely that the money will be withdrawn before long to help solve a crisis problem (often in another sector), with the promise (that is not fulfilled) that the amount taken will be restored to the account at a later date. Commercialised utilities (Section 11.1.4) that have independent management and accounts may sometimes be able to build up sinking funds so that they can replace ageing equipment. Private sector operators generally borrow for capital purchases, and so contracts should be of similar length to the economic lives of the main items of equipment, so that loans can be paid off at a reasonable annual rate.

10.3.2 Interest on capital and opportunity cost

There are different ways in which a local authority can obtain the vehicles and other equipment needed for its solid waste management services.

- Equipment may be provided by regional or central government as a grant. In this case the local authority does not have to pay interest on the sum of money involved. However, unless there is a formal and dependable system for replacing the equipment when it reaches the end of its economic life, the local authority should make its own provision by the creation of a *ring-fenced*[41] sinking fund to provide finance for future purchases when the equipment becomes obsolete or when further equipment is required for expanding the service.
- The equipment may be leased. In this case the lease charges cover both depreciation and interest charges.
- The local authority may have to borrow the money to purchase the equipment. If the loan is on a commercial basis, interest must be paid on the money borrowed. In this case the bank loan interest rates should be added to the depreciation in calculating the financial cost.
- The local authority or other service provider may have funds available to purchase the equipment from its own reserves. In this case the *opportunity cost* of this money must be taken into account if the true financial cost is to be understood. The opportunity cost[42] is the interest which that money could be earning if it was on deposit with a bank or invested in a secure high-yielding stock.

40. *A sinking fund is money set aside at intervals for payment of a particular liability (in this case the purchase of new trucks) at a particular date (the end of the economic life of the trucks).*

41. *If a fund is ring fenced it means that it can only be used for a particular purpose, and is protected (by the "ring fence") so that unauthorised officials or other departments cannot get access to it.*

42. *The opportunity cost can also be considered to be the income that could be gained if the capital had been used for another project or in another way. If the money is used to buy vehicles it is not possible to get benefit from another use of the money. The opportunity cost is the potential income that has been lost by investing it in vehicles, and is expressed as a percentage of the capital sum, in the same way as an interest rate.*

Whichever method of financing is used, the cost or value of the capital used must be included to get a reliable estimate of total costs.

Interest rates and opportunity costs vary greatly between different countries and in general are highest in countries where there are high inflation rates.

A formula for combining interest and repayment is shown in Annex A3.9.5.

When all operating and financial costs are taken into account, it is possible to calculate the total costs of a collection service. (There is an example of comparative calculations of total unit costs in Annex A3).

An alternative approach for combining capital costs and recurrent (annual) costs – so that different systems and projects can be compared – is to calculate the net present value, which is the sum of money needed at the start of the project to cover all the costs of the project for the whole period of the project. This approach assumes that cash to be used in later years is invested in order to earn interest.

Then cost recovery systems can be set up to pay these costs and so make the service sustainable.

10.4 COST RECOVERY

10.4.1 Introduction

In many developing countries, local authorities are expected to provide services without an adequate long-term funding base, and often with insufficient funds to even meet their day-to-day operating costs. It is therefore essential that there is a full understanding of both the true operating costs (needed to provide a satisfactory cleansing service) and the real long-term financial costs, so that the financial planners can budget accurately.

Accurate knowledge of the operating and financial costs (as outlined above) is needed by the city treasurer so that long-term financial plans can be developed to take into account all the costs of the waste management service. A funding system must then be put in place and operated effectively to ensure long-term sustainability of the service.

There is a tendency for citizens to expect local authorities to provide a waste management service at little or no cost to the householders and businesses, however unrealistic this may be. In many countries in the twentieth century no special fee was charged for waste management. Increasingly we are seeing that yesterday's arrangements are unable to cope with today's challenges, particularly the rapid growth of urban areas and the need for improved standards. There are signs of a change in attitude. Many *willingness-to-pay* surveys have shown that people of all income levels, even from the lowest income groups, understand the need for a clean environment and are prepared to pay for a good waste collection service.

However, it has also been frequently found that there is a lack of confidence on the part of the householders and the business community in the ability of local authorities to use the revenue from fees to provide a satisfactory service. This lack of confidence is evident in the reluctance to pay new waste collection charges before a reliable and adequate service is seen to be operating. It is therefore advisable that an improved service is being provided before increased service charges are introduced.

There is a general principle that a waste producer should pay for the collection and removal of his waste, and payments should be in proportion to the amount of waste generated. Whilst this may be broadly accepted as logical and ideal, in practice it can lead to illegal dumping of waste (to avoid the charges) in the absence of an effective enforcement system and majority support for this principle among the citizens. Paying according to quantity may be feasible for large generators of waste (such as large industries and hotels), but is very difficult to operate in a practical and reliable way for sources producing smaller quantities. (The best option is pre-paid bags [Box 5.2], but even this simple system has drawbacks). A compromise is to charge a higher fee to residents in more affluent areas, where it is presumed that more waste is generated and that there is a greater ability to pay. Sometimes solid waste management fees are linked to water or electricity consumption.

10.4.2 Cost recovery systems

It is more difficult to collect fees directly from householders for solid waste management than to collect payment for water or electricity. This is primarily because solid waste management is a public good which benefits others as much as the person paying the fee. In contrast, water and electricity are private goods which are clear personal benefits and for which we pay according to our use.

There are a number of ways in which the local authority can recover the costs of any waste collection service including:

a) **Government grants** – In some countries the central government provides all or some of the income of the local authorities. If there is a particular allocation for waste management, it is important that proper cost studies are carried out so that the funding agency is aware of the actual solid waste management costs and that they are properly budgeted for, including regular capital allocations for replacing old equipment. (Unfortunately, most city administrations do not know the total costs of their solid waste management services, partly because of the way their accounting and budgeting systems are set up.) Without a regular capital budget there is a tendency for the system to revert to a crisis management modality with no regular vehicle replacements and capital being provided only when the system has deteriorated to an unacceptable extent. In other cases, local administrations may receive grants from central government, and be relatively free to use the money as they wish, so it is the responsibility of the local administration itself to set aside sufficient capital and recurrent resources for solid waste management.

b) **Refuse Collection Charges (RCC)** – A monthly charge can be levied on each household and business, according to the economic status of the household and the size of the business. The costs of collecting these charges may however take up a significant amount of the funds collected and the legal costs involved in enforcing this collection may be high. A scheme in which 90% of the billed amount is actually collected is regarded as a big success; usually the rates of fee collection are considerably lower. It may be possible to ensure that shops and offices pay their charges by refusing to renew their licences or to grant permits unless the fees are paid.

   If a private sector operator is involved, the charges may be collected either by local government or by the private operator. If there is a low level of confidence in the local administration, the citizens may prefer to pay the RCC directly to the private operator, expecting that this money will all be used for the specified purpose. In some cases the local administration may prefer that the private operator takes responsibility for this task, because of the large amount of work involved and the risks of non-payment. Local government should support the private operator in the collection of RCC, by officially introducing the private operator to the citizens and by taking measures to enforce payment.

c) **Refuse collection charge added to an existing service** – A refuse collection charge can be added to the bills for an existing service, typically electricity or water which are metered and billed on a monthly basis. This involves a close working relationship with the particular utility. Normally a commission of around 5% of the revenue collected is paid to the collecting agency.

   Electricity supply is a suitable service for collecting this charge. The agency responsible for collecting payments for electricity consumption is likely to have a regularly updated list of all households and businesses. In general the more wealthy householders and commercial premises use more electricity than the lower-income users, so there will be cross-subsidisation from the high-income residents to the low-income groups, if the waste management charge is linked in some way to the amount billed for electricity consumption. In this case there is also a link between waste quantities and the level of the fee, since larger and more affluent households that use more electricity can be expected also to generate more waste. The poorest areas may not even have official connections and so would pay nothing for refuse collection (though this may be used as a reason for providing no collection service). In theory, water or electricity supplies can be cut off because of refusal to pay the refuse collection charges, but in practice this is often not politically possible.

d) **RCC collection only from businesses** – The refuse collection charges may be linked to the issuing of business licences, and collected only from those who require licences to carry on their business. Although this puts the whole burden for the waste collection service onto the business community, this is basically quite a fair method because all householders purchase their goods and services from the business community. Shops and services will increase their prices to compensate for the payment of the fee. With this system, the payment made by any householder towards the costs of waste collection will be in proportion to his/her spending, so that, in this way also, the wealthy will be cross-subsidising the lower-income areas. Informal street traders in the low-income areas buy their goods from the formal business community so that any cost increases due to increased business licences will *trickle down* to the whole population. However, this arrangement may encourage some traders and providers of services to operate informally, without licences.

e) **Local taxes on commodities** – The *octroi* taxation system in India, in which local government imposes a tax on all items brought within its boundaries, has been a source of revenue for cities for decades. Elsewhere, a major city has introduced local taxes on a wide range of commodities to cover the costs of its waste collection service.

f) **Contracting directly with households** – Where there is an unsatisfied demand for a solid waste collection service, private operators often contract directly with waste generators, whether households or businesses, to provide a collection service (see Section 11.2.1). If the generator does not pay, the service is no longer provided. Sometimes special plastic bags are issued to indicate who has paid for the service (Box 5.2). Households who decide not to pay for this service will probably dump their waste illegally at a short distance from their houses. Some householders in neighbourhoods where there are community containers may contract with individuals to take their wastes to these containers, rather than carrying it themselves, and in this way they can exercise choice, paying more for a more convenient service.

g) **Littering fines** – Substantial fines for *fly tipping*[43] and littering with strict enforcement can be used to supplement waste management revenues.

10.5 MANAGEMENT OF FUNDS

The reason for collecting separate charges for solid waste management is to ensure a regular source of revenue and to have some control over the size of the budget. These benefits are lost if the fee income is paid into a general municipal or national account or if the cleansing manager has no control over the level of the charges, and cannot increase them when more revenue is needed. Unfortunately both of these undesirable situations are relatively common. When the fee income is paid into a general municipal fund, the distribution of it depends on the head of the municipality, and if the amount of the fee is decided by politicians, they may set the fee to avoid any opposition rather than according to what is necessary to sustain the service.

The operating budget must be adequate to pay all labour and energy costs as well as:

- good maintenance of the vehicles and other equipment according to a scheduled service and preventive maintenance programme. A stock of all essential spare parts (including filters, tyres, clutches, brakes, steering parts and electrical parts) must be maintained at all times;
- a fast repair service when vehicles break down and when major repairs are required, to minimise downtime;
- funds to cover the immediate purchase of parts for occasional major repairs following accidents or unanticipated breakdowns, and for major overhauls of engines and other large components.

The funds for all of the above items should be immediately available to the cleansing or workshop manager. This manager should have authority for immediate purchases up to an appropriate limit without the need to look for several tenders for each item and to obtain the approval of the financial controller. Waiting for bids and approval for urgent purchases can cause serious delays if the financial controller is under pressure from different departments. (In many situations delays and serious costs are caused by the very systems which are put in place to keep costs under control.) Annex A2 on preventive maintenance includes a procedure for estimating *out of service* costs, to show the effects of administrative delays and other shortcomings related to maintenance.

For any collection system to be sustainable, it is essential that the revenues available to the solid waste management service are equal to the operating and financial costs set out above. The financial pressures experienced by almost all local authorities encourage the tendency to concentrate on the short-term operating costs and ignore the longer-term financial depreciation costs. This tendency will inevitably result in a crisis in a few years' time, as the equipment ages and requires replacing.

The phased replacement of equipment is essential to long-term sustainability. Any local authority that is serious about having a municipal waste collection system that is dependable must have a full understanding of the financial costs as set out above.

10.6 ECONOMIC COSTS AND SHADOW PRICING

Policy decisions at Government level, and deliberations regarding financial support from the development banks and donors, are often based on considerations of the overall effects of the proposed investments. A project or programme is selected if it can be demonstrated that the proposed course of action will be more beneficial to the national economy than alternative proposals for the use of the available funds. The benefits of the proposal are compared with the costs, expressed in economic terms that reflect the overall costs and benefits to the nation as a whole. When it is difficult to quantify the benefits (as is often the case in solid waste management projects), deci-

43. *Fly tipping is the illegal dumping of significant quantities of waste, often in urban areas. It is generally done to save money by avoiding to take the waste to the official disposal site. It is different from littering in that it involves larger quantities of waste and is usually planned in advance.*

sions may be made according to the lowest economic cost. This brief introduction is not sufficient to explain how to perform an economic analysis, since it mentions only some key points.

Shadow pricing is used in economic analysis. It takes into account factors which adjust the relative importance of the actual financial costs to show the net cost to the country's economy.

a) **Shadow cost of labour** – The shadow cost of labour allows for any social benefits of employing labour, deducting from the actual wages the cost to the state of supporting that person and his family if he was not employed. It also deducts any taxes which that person will pay, because this money returns to the state and so is not a net cost to the national economy. The shadow cost of labour is therefore less than the actual wages paid.

b) **Shadow cost of fuel** – In many countries there is an excise duty on fuel so that the net cost of the fuel to the national economy is less than the amount paid by the local authority or a private sector service provider. In some countries the fuel is subsidised and in this case the actual cost to the local authority is less than the actual cost to the economy. If fuel is imported, the difficulty of obtaining foreign exchange to pay for it may increase the shadow price.

c) **Shadow cost of vehicles and equipment** – Customs duties may be payable on imported vehicles and other equipment, and also value-added taxes when they are purchased by the municipality or a local entrepreneur. These taxes return to the national exchequer and the result of this is that the shadow price is less than the amount paid. Difficulties in obtaining foreign exchange may increase the shadow price. Local manufacture of vehicles and equipment results in a lower shadow price because of the employment generated and the taxes paid. Shadow pricing, in most cases, favours locally manufactured equipment because the shadow price is less than the financial price (that is, the cash price that is actually paid).

d) **Shadow cost of maintenance** – The shadow cost of maintenance is reduced by any duties or taxes paid on spare parts and incorporates the shadow cost of the labour used to maintain the equipment.

It can be seen from this brief introduction that the calculation of shadow costs is a complex matter requiring the assistance of a specialised economist. However many governments have standard shadow factors which can be used to provide an approximation.

Local authorities and private sector service providers should make their selections of equipment according to financial analysis, using actual prices, because they are concerned with minimising their actual expenditure. On the other hand, economic analysis, using shadow prices, is needed for setting national policy and for obtaining loans from development banks.

Summary points

- Planning for, and providing for, the phased replacement of vehicles is an important function of management. Unfortunately many municipal managers are not allowed to do this.
- There should be a clear link between the setting of the level of service and the funding that is available, so that there is sufficient income to pay for the service.
- Since solid waste management is a public good, a direct service charge can only be effectively collected if there is a means of obliging or motivating householders to pay it.
- Delays in making cash available for maintenance requirements can be expensive.

11 INSTITUTIONAL ARRANGEMENTS

Successful solid waste management requires the integration of many organisations and groups into a partnership. National government often has a relatively minor role, but considerable influence. Local government is normally responsible for solid waste management, even if private sector contractors are engaged to provide services. Small family-based enterprises and informal sector rag pickers are often very involved with waste. NGOs and community-based organisations can have important impacts in organising local services, raising awareness and supporting vulnerable individuals. Householders are often asked to pay fees that enable the waste collection service. Individual citizens have an opportunity to improve or degrade the neighbourhood each time they have something in their hands that they no longer want. If all these different groups can work together in co-operation, the problem is solved. When there is a lack of shared concern and partnership, the task of keeping a city clean and healthy is a continuous struggle. These *institutional* aspects of solid waste management are often ignored in planning and managing. This chapter aims to show that many agencies and organisations have an important part to play, and how institutional factors have an influence on the design and management of solid waste collection systems.

11.1 THE PUBLIC SECTOR – NATIONAL, REGIONAL AND LOCAL GOVERNMENT

National, regional and local governments all play a role in solid waste management.

11.1.1 National Government

In general, national governments play a small role in solid waste collection services. The main impact is often from policy decisions, such as the extent to which the private sector is to be involved. Laws, regulations and standards are usually established at national level, but often they have little to say about collection operations, being generally more concerned with financial and environmental aspects. Central government may control the expenditures on solid waste management, and in some cases cover the employment costs directly. In some countries there are requirements that waste collection operators must be licensed or registered. International development co-operation agencies often relate to the national level, and in such cases national level officials may take decisions concerning waste collection equipment, even though they have little knowledge about the day-to-day difficulties faced by local waste collection operations. Research institutes are usually linked to the national government, but research work tends to focus on recycling and disposal rather than collection. National-level agencies are sometimes asked to identify candidates for training for international training programmes, and, perhaps because of their lack of contact with the responsible organisations, they seem to have difficulty in nominating suitable candidates.

In some countries there is no ministry that is designated as being responsible for solid waste management operations, though there is usually an organisation that is responsible for environmental monitoring.

11.1.2 Regional Government

It is difficult to generalise about the role played by regional government in solid waste management because it varies from country to country. The size of a country has a major impact on the roles assigned to regional government. Regional administrations are more likely to have control of finances than to be responsible for day-to-day operations, and they are more likely to be involved in disposal rather than collection, especially where regional disposal facilities are used by several towns and cities. (In some nations, regional government is responsible for running disposal operations, because of the economies of scale of regional landfills and the difficulties faced by cities in finding land for disposal within their own boundaries.)

11.1.3 Local Government

Usually, solid waste collection is the responsibility of municipal or local government administrations. The actual sweeping and collection services may be operated by municipal employees or handed over to the private sector, as will be discussed shortly. When the private sector is involved, the public sector still has very important roles to play, and weaknesses in the administration of private sector participation – particularly in the preparation of the contract documents and in the monitoring of operations – can have very damaging effects on the success of private sector involvement. Therefore, considerable capacity building of local government is needed in preparation for involving the private sector.

Local governments often work under a national legal framework rather than under a local one. This makes it a difficult and lengthy process to change the framework to suit local conditions or preferences, such as private sector involvement, community involvement and introducing or modifying penalties.

Solid waste collection requires the co-operation of the public, and failures in the service are clearly visible to the citizens. In any situation in which local government depends on the support of the citizens (as for example where there are competitive elections) the provision of a good solid waste collection service is of considerable importance in maintaining the support of the community.

The budgetary responsibilities of municipalities vary, but it is common for solid waste management expenditures to be the largest component in a municipal budget. The sweeping and collection services generally absorb the largest proportion of overall solid waste management expenditures, disposal involving smaller operating costs. In spite of this high financial profile, the management of solid waste collection services is often left to personnel with little training in this field and with many other responsibilities, and decisions regarding the acquisition of equipment are taken by officials who have little understanding of the factors that should be taken into consideration. The consequences of this vacuum in expertise are often poor services and high costs.

11.1.4 Commercialised utilities

Government administrations must often work within restrictions which hinder their ability to plan and to operate efficiently. As will be explained in Section 11.2, the private sector is not bound by many of these restrictions. It is possible to set up a unit within the government sector that has many of the advantages of the private sector. Such units are called commercialised utilities. They are commercialised in that they operate in a similar way to commercial organisations (the private sector) and they are utilities because their purpose is to provide one particular service (in this case, solid waste management). Commercialised utilities are staffed by public employees, and any profits are channelled into reserves or public funds, rather than going to an individual or shareholders. Their accounts must be segregated or ring-fenced, covering all expenditures and income related to the work, and inaccessible to government officials outside the utility. Commercialised utilities are generally responsible for raising their own income, though often they cannot set tariffs without the agreement of municipal or regional authorities. Commercialised utilities may provide a service to one city or to a group of towns and cities. Their boards usually comprise senior municipal administrators; the board instructs a managing director who is responsible for day-to-day management.

Commercialised utilities cannot be expected to be effective unless they have a high degree of independence. This independence must be respected by senior local politicians and administrators, who should not force the utility to employ staff that it does not want, and who should not take funds from the utility (particularly its reserves for replacement vehicles) for other purposes. If such conditions are upheld, a commercialised utility can benefit from many of the advantages of the private sector, yet retain the focus of providing a service according to the general direction of municipal leaders.

A good example of a commercialised utility (that provides secondary transport and disposal services to eleven communities) has been described by Scheu and Borno [2000].

11.1.5 Links with the public

Unfortunately, many municipal officials, having training and experience mainly in technology and public administration procedures, are not well qualified to encourage community involvement in planning and operations. This may encourage them to try to avoid the whole subject of links with the public, since they prefer to concentrate on issues with which they are familiar. In many cases the lack of experience of municipal officials can be compensated by involving consultants, academics and non-governmental organisations (Section 11.4).

A further barrier to the development of strong links with the public is the tendency to an authoritarian approach, municipal officials believing that it is their duty to make decisions as they consider best, rather than consulting the public before deciding. A lack of the accountability that derives from elections is another reason why officials do not consult or inform the communities they govern.

A number of factors in a solid waste collection service are of considerable interest to residents and the business community. The frequency and time of collection, the method of collection, the type and location of waste containers and the costs of the service are all important to the general public. Consulting the public in matters that affect them is an important first step in gaining their support. As much as possible, their opinions should be incorporated into the planning process. If their wishes cannot be accommodated, it is important to explain the reasons why. Open lines of communication can be very effective in gaining co-operation.

Local government officials may believe that they understand the wishes of their communities, but there are many indications that this is often not so. The opinions of the public can be ascertained by conducting questionnaire surveys, and by listening to opinions expressed by focus groups and neighbourhood committees. Stakeholder analysis considers the viewpoints of all those who might be affected by decisions that are to be made.

When decisions have been made, attention should also be given to informing the public about them, especially regarding the services that are to be provided (including the timing, the point of collection, the types of wastes that will be collected), and fee collection. The public may also be requested not to give their waste to unlicensed private operators, to report any illegal dumping of waste on open ground, in canals etc., to sweep outside their homes and to refrain from burning waste. It is also important to inform the public regarding how they can make complaints in connection with any shortcomings in the service. Any attempt to introduce at-source segregation of recyclables should be accompanied by an extensive public information programme. The wider issues of environmental awareness are normally the responsibility of the national environmental agency.

Waste management organisations should take action to present a good image to the public. This can be done by encouraging the reporting in the media of good news in the field of solid waste management, (such as the extension of the collection service to a new area or the purchase of new equipment) rather than leaving the newspapers and television to report only bad news. Clean and well-painted carts and vehicles, and clean uniforms can be effective in presenting a positive image. Site visits to workshops and good disposal facilities can also win friends and approval.

A well-run complaints system not only improves relationships with the public but also provides useful monitoring information regarding the operation of the sweeping and collection services. If the local government department shows appreciation for complaints, treats people making complaints with respect, and provides feedback on the action that is taken as a result of the complaint, citizens who were initially hostile to the waste management service can become its friends.

11.2 THE PRIVATE SECTOR

In simple terms the private sector can be described as a group of people who work together to produce items or provide a service with the aim of generating a profit which is for the benefit of some or all of them. Employees are not paid directly from public funds and the resources used are not owned by government. The private sector can be considered in two parts – formal and informal. Formal organisations operate within the legislation and taxation framework, being officially registered and licensed. Informal operators are not officially registered, operate without a licence and pay no tax on their incomes. This section is concerned with the formal private sector and Section 11.3 with the informal private sector. Both sections will provide only brief introductions; more information can be found in the publications listed in the Bibliography in Annex A7.2.

11.2.1 The range of options

There is a huge variety of mechanisms for involving the formal private sector in solid waste management. Unfortunately potential clients often do not consider the whole range in order to choose parameters that are best suited to the local situation, but limit their choices to what has already been used in local experience. When the most appropriate arrangement is not carefully selected, there can be negative consequences in terms of costs and sustainability. There are four basic models of the relationship, and many variations within these models. There are also other variables that should be considered. It is beyond the scope of this section to provide all the information needed to select the most appropriate arrangement; the aim here is to illustrate that the range of possibilities is very wide. The four basic models are:

a) **Contracting** – In this arrangement, the client, usually a municipality or regional authority, defines the work that is to be done and selects a private sector service provider. Payment is made by the client. Contracts in solid waste management are generally for a much longer period than construction contracts, and have a higher ratio of operating costs to capital costs than contracts in, for example, the water industry, so model contracts should not be borrowed from these other sectors without modifying them considerably.

b) **Franchising** – The selected private sector franchisee is awarded a monopoly to provide a defined service in a defined area for a defined period. The franchisee is responsible for collecting payment from the beneficiaries or customers.

c) **Private subscription or open competition** – Service providers, who have been qualified or licensed by the local authority, may compete with each other to provide a service to individual clients or subscribers. In the case of collection of domestic waste, this means making a contract with each household. Private operators under such arrangements may be unwilling to provide a service to areas of difficult access (such as traditional core districts or unplanned housing areas) and collect waste only from households which pay them.

d) **Concession** – In cases which involve the construction or purchase of large facilities (such as landfills or recycling plants) a concession is awarded to the selected operator to build and operate the facility, and, usually, at some stage, to transfer ownership of it to the responsible public body. The private sector concessionaire must recoup his expenses from fees charged to users or income from the sale of products.

There is some variation (and apparent carelessness) in the use of terminology in this field. The definitions used in this publication are the same as those used by Cointreau-Levine [2000]. This reference is recommended for further reading.

In addition to selecting from the models listed above there are other questions that need to be considered, such as:

- To what extent should the private sector be involved – just providing advice or management, providing a workforce to use publicly-owned resources, or providing both human and physical resources;
- Which tasks will be undertaken by the private sector, and how will these tasks be defined and measured?
- Who will pay for the service? Who will monitor performance? Who will own the machinery and facilities?
- How will a franchisee's monopoly in the designated service area be enforced?
- What will be the duration of the arrangement? Under what circumstances and by whom can the arrangement be terminated? How will the risks be shared?
- What sizes and types of organisation may be involved? Should the work be divided up into small packages so that small, local firms can bid? What restrictions are necessary regarding the methods and technologies that are to be used – can labour-intensive methods and capital-intensive methods both be considered? Will the private sector operator be obliged to take on the existing public sector waste collection and sweeping staff?

Unfortunately some local government administrations have rushed into arrangements with the private sector without considering these questions and the result is often that the chosen arrangement is not the most effective. Agreements which do not last for the full economic life of the vehicles and other necessary equipment discourage the purchase of specialised vehicles. This results in the use of inefficient general-purpose vehicles (typically standard open trucks) which can easily be sold or put to other work if the contract is not renewed after one or two years.

11.2.2 Advantages and disadvantages of private sector involvement

The main advantages of involving the private sector are usually:

- Private companies can access capital (from loans or reserves) in order to purchase the most suitable equipment and so minimise total expenditures;
- Private sector organisations often specialise in a small number of services and so have considerable expertise in these fields;
- Private enterprise is motivated by profit and has greater freedom to use its money effectively, and so is able to operate more efficiently than local government.

However, If the relationship with the private operator is not managed well, there can be many problems. Disadvantages which are harder to avoid include:

- A loss of expertise in the public sector,
- The risk of a monopoly situation developing, so that there is no alternative to the particular service provider,
- Corruption (bribes paid to inspectors and officials to overlook shortcomings and associated penalties).

11.2.3 Prerequisites for successful involvement of the private sector

There have been many disappointing experiences with private sector participation in low-and middle-income countries (for example [Awortwi, 2004]). To a large extent, the success of a relationship with the private sector depends on the local government partner more than the private sector service provider. Local government often lacks the capacity and motivation to innovate or change. Some of the key factors for success are:

- the preparation of a comprehensive and well-written contract which is respected by both sides,
- political will to make the relationship succeed, including the concept of partnership and teamwork (both sides having rights and obligations, and having mutual respect), transparency and realistic arrangements regarding the transfer of staff;
- financial capacity – the ability to pay the contract fees without overdue delays or to support franchisees in fee collection including the enforcement of fines for non payment, (The introduction of the private sector is often linked to the introduction of a service charge, and this can result in undeserved unpopularity for private sector services and insufficient income.)
- a serious and fair approach to monitoring, penalties being imposed according to contract procedures in order to ensure good performance;
- citizen involvement – co-operating with collection procedures, paying fees and neighbourhood monitoring of operations.

If a city is divided into a number of zones with separate contracts for each zone it may be advantageous for the municipality to retain one zone under its own management and service so as to maintain its expertise in this field, including an understanding of the problems of the contractors. If one of the contractors fails, there is more capacity for taking over, perhaps just on a temporary basis.

11.2.4 Micro- and small enterprises

Private sector organisations involved in solid waste management may be very large – such as international companies providing services for many large cities in many countries – or small – such as small community-based groups that are contracted to provide a collection or sweeping service for their local neighbourhood. Microenterprises are often partly formal and partly informal [Section 13.3]. Micro- and small enterprises may be contracted to provide labour-intensive waste management services; in such a role they are very vulnerable to delayed payments and may have little bargaining power with their client. If treated fairly they can provide a good service because of their links to the neighbourhood where they work and their own interest in living in a clean environment.

11.2.5 Impacts for refuse collection

The decision to involve the private sector in solid waste collection can be expected to have the following results relating to waste collection vehicles:

- Selection – The equipment that is selected is likely to be more suitable since the private sector has access to capital that allows it to choose the most efficient machines (which are not necessarily the cheapest), and specialised companies usually have access to experienced specialists.
- Better maintenance can be expected because a private company should be aware of the costs of poor maintenance (especially in terms of low utilisation of equipment) and so it will employ good mechanics and garage managers to minimise vehicle downtime. Private sector organisations generally have less bureaucracy than the public sector and so can approve expenditures with a shorter delay, so that vehicles can be repaired in a shorter time. Local authorities are often inhibited in retaining good maintenance staff by rigid local authority wage structures.
- Better utilisation of equipment and resources is generally achieved by the private sector because of financial pressures and the aim of making a profit.
- Better appearance of waste collection vehicles – because they are replaced before they are very old and because the operator can be obliged by the contract to wash them regularly. Clean and neat equipment can raise public appreciation and the status of waste management, and even of the city administration.
- Better management of depots and servicing facilities. There is often a very clear difference between public sector and private sector vehicle depots. The local government procedures for getting rid of useless vehicles and wrecks are often very long and complicated, so scrapped machinery is often just left in the depot, using up valuable space. The private sector can easily sell old vehicles and scrap equipment, and so private sector garages and workshops are generally much cleaner and better organised.
- There may however be a problem when it comes to the transfer of all or part of the municipal labour force. Fast loading of vehicles requires fit, young men and private operators may simply discard older employees who are unable to keep up with the loading speeds required. The younger transferred loaders may work at a slower rate to allow for the older people in the crews and so supervisors and managers may become displeased with the transferred loaders. Instead of transferring older men to the private sector, the municipality may have other jobs, more suited to their declining strength, to which they can be transferred (such as tending: parks and gardens and water services).

Micro-or small enterprises that are responsible only for primary collection depend on the secondary transport system for the removal of the waste they collect. This interface – both the physical and the organisational arrangements for transfer – must be carefully managed, otherwise the collected waste accumulates and they are blamed for a failure that is not their responsibility.

11.2.6 Relationship with the public

Any contract or agreement concerned with services provided by the private sector should specify the responsibilities of both parties for tasks related to consulting, informing and involving the public. If complaints are to be received by the private sector service provider, the local government client should monitor them and the action taken in response to them.

Box 11.1 Example

Community-based primary collection

Returning home to Dhaka, Bangladesh after working abroad for some years Mahbob Khurram was shocked to find piles of waste on the street where he lived, so he organised a collection service for his neighbourhood, using two tricycle carts (known as rickshaws) and employing ten labourers. The waste is carried in a large steel box fitted to the back of each rickshaw. The operators sound a horn to ask residents to bring their waste to their rickshaw and they provide a doorstep collection service for a small extra charge. Some residents in upper storey apartments lower their bags of waste using string. The waste is taken to a transfer area from where it is picked up by municipal vehicles. When the system was operating well he started collecting a fee from the households, and only 15% default regularly.

This approach has been copied widely and has been operating for more than ten years. There may be as many as 250 schemes resulting from this initiative.

Mahbob is convinced that these schemes should remain small, each collecting from no more than 1,000 households. The operators are all local people who are known to the residents, and this connection assists in fee collection

source: TVE.org

11.3 THE INFORMAL SECTOR

The informal sector operates in many different ways. As was mentioned in the last section, the informal sector operates outside commercial legislation, and often on a small scale, being based on family units each with a small turnover. In spite of the small scale of the units involved, there can be a high degree of networking and organisation, as evidenced by the network of dealers involved in trading and processing recyclable materials. In some cases co-operatives and support organisations have been set up, but often there is no negotiating partner that represents informal sector workers.

In some countries informal sector waste collection and recycling are dominated by particular ethnic or religious groups, such as minority Christians from rural areas in Cairo, Egypt, Afghan refugees in Karachi, Pakistan and Romany groups in Eastern Europe. Waste recycling may be the first means of earning a living that poor rural people find when they arrive in a city.

The informal sector often provides an extensive solid waste collection service. For example, in Monterrey, Mexico, a thousand or more informal sector waste collectors each collect about 500 kg of waste each day and earn about 3.3 times the official minimum wage. This is in addition to the municipal waste collection service. [Medina, 2005]. Data from elsewhere in Latin America also indicate that informal sector waste workers usually earn more than the local minimum wage [Lardinois, undated].

Most informal sector income comes from trading and processing recyclable material and items from solid waste, but some income is also received in return for services, such as sweeping and waste collection. Recyclables may be collected or purchased from door to door, or may be separated from wastes in the street, at transfer points, during loading and transport of the wastes, or at the disposal site. The collected material may then pass through several stages to sort, clean, bale or grind it before being sold to factories. There is a considerable international trade in plastics, used electronic goods and metals.

Municipal street sweepers and waste collectors may also be considered to operate in the informal sector when they select and sell recyclable materials for their own profit or undertake additional cleaning work for households and businesses. The right to work in streets where there is considerable income potential from such activities is sometimes bought and sold informally, but in a very structured way.

In some cities there are tens of thousands of informal sector waste workers[44]. Informal sector waste management clearly provides a significant means of survival for many city dwellers, and the informal sector should be considered in the planning of any waste management initiative in any urban area where it is active.

It is often reported that only between 40% and 70% of

44. *In Karachi, Pakistan, a city of 12 million people, it is estimated that informal sector activities in solid waste management generate an annual turnover of US$ 20 million and provide employment for over 55,000 families. [Rouse, 2006].*

the waste of a city is collected by the formal system. In such situations the informal sector waste pickers have easy access to the uncollected waste – though often the uncollected waste is in the low-income areas of a city where the waste has a lower recycling potential and so is of less interest to waste pickers than waste in the commercial and prosperous residential areas. However, the start of a new collection system, which aims to collect all the waste, may severely reduce the access to waste by informal sector waste pickers.

11.3.1 Strengths and weaknesses of the informal sector

a) Strengths – The informal sector can be very efficient in performing manual work which requires a low capital input. In such work informal sector workers are often able to make a profit from work which would be unprofitable for the formal private and public sectors. The use of unpaid family labour and the willingness to work in contact with the waste keep costs below those of formal operations.

Informal sector workers know that it is in their direct personal interest to provide materials and services that satisfy their clients, because if a client or customer is not satisfied they immediately lose their income. They work only in fields where there is a clear demand.

b) Weaknesses – The informal sector often has few links with the formal sector, so that the operations of one sector are often counterproductive to the other, and misunderstanding, competition and even hostility commonly characterise the relationships between the formal and informal sectors.

If an informal sector primary collection scheme depends on the formal sector for the removal of collected waste, the informal sector is often blamed when the formal secondary collection service is not reliable.

Informal sector workers often show very little care for the environment. They may dump unwanted wastes in unsuitable places and process recyclables in ways that cause serious air and water pollution. The reasons for this behaviour are likely to be a combination of ignorance of environmental considerations and ways of avoiding pollution, and a lack of money to operate in an environmentally acceptable way.

11.3.2 Contributions and problems of informal sector involvement

a) Contributions – Among the many arguments for encouraging informal sector operations are the following:

- Livelihoods – informal sector waste management provides livelihoods for significant proportions of the populations in many cities. Without this source of income, many more citizens would be destitute and beggars.
- The quantities of solid waste requiring transport and disposal are reduced. Every ton of waste that goes to an open dump causes pollution, and there is an expenditure associated with every ton that is landfilled. Transporting waste to distant disposal sites involves cost. By returning a proportion of the waste to the economy as a useful material, the expenditures on transport and disposal are reduced, and pollution is reduced.
- The informal sector is often able to provide services in areas that the formal sector is unwilling to serve – for example, areas where the access is difficult and low-income areas where fees must be lower.
- By obtaining a proportion of required raw materials from the waste stream, the demand for virgin raw materials is reduced, and the energy required to produce production materials is reduced. Recycling thereby contributes to the conservation of natural resources.
- Recycling provides materials that are cheaper than virgin materials and imported goods, so that products can be manufactured from recycled materials that are more affordable for low-income groups.

b) Problems – The problems often associated with informal sector collection and recycling operations can be categorised as environmental, health-related and aesthetic.

- Informal sector waste collectors may unload the waste that they have collected in unauthorised places to avoid a long journey to the official disposal site. Waste may be scattered on streets and open spaces by waste pickers sorting through collected wastes. Disposal operations are sometimes disrupted by waste pickers working close to heavy machinery, setting fire to wastes, or even controlling operations on the site by threatening violence. Pollution can also be caused by crude processing techniques.
- Waste pickers put themselves at risk through skin contact with the wastes and by inhaling dust and smoke. The health of the general public may also be threatened by the reuse of contaminated containers and medical supplies (especially syringes and needles). Hazardous wastes from hospitals, clinics and some factories should never be allowed to enter the general municipal waste stream where they become a serious

risk of infection to formal and informal workers during collection and disposal. Many informal sector waste pickers on disposal sites work with inadequate shoes and are at high risk from infectious and other hazardous items.

- Some informal sector waste collectors and pickers use animal-drawn carts or handcarts that are in very poor condition. City authorities sometimes object to the use of such carts because of their appearance, which gives a bad impression of the city, and because of traffic congestion caused by their low speed and the habits of their drivers.

11.3.3 Relationships with the informal sector

a) Attitudes – Residents whose waste is collected by the informal sector often have a very positive attitude towards the person who collects their waste. This is especially true when the service is very convenient, the waste being collected from their doors. The costs may also be lower than for a formal collection service because the collectors make much of their money from recycling what they collect. There may also be the influence of personal contact. In general, householders are only concerned that their wastes are removed from their immediate locality, and so they do not care if their wastes are taken for satisfactory disposal or just dumped elsewhere, perhaps on vacant ground or in a canal. This shorter transport distance is another reason why fees for informal sector collection may be lower.

In other cases, attitudes may be much more negative. There may be prejudice against the informal sector workers because of the work that they do, or because of their nationality or ethnic origin. In some places they are blamed for drug trafficking or other social problems. The consequences of this prejudice may be a refusal to discuss with them or police harassment. The work of the informal sector may be undervalued by officials and citizens who consider that only sophisticated machinery should be used for waste collection. Medina [2005] defined the informal sector in terms of the methods used (low capital and very labour-intensive) and operation outside the taxation system. He also categorised four attitudes to the informal sector: – repression, neglect, collusion and stimulation.

It is often believed that waste pickers are quite wealthy, but this is probably very rarely true. Although their incomes are small, they are often subject to demands for payments from police and officials. The small number of people that organise collectors and waste pickers may, however, have considerable wealth.

Public attitudes towards waste pickers in parts of Brazil have been improved considerably as a result of a concerted campaign involving many stakeholders, and the official recognition of their work as a profession [S.M. Dias, 2006]

b) Conflicts – There may be conflicts with the formal sector. These may be almost hidden – such as when informal sector waste pickers go to street containers and scatter the contents in their search for recyclables before the official waste collectors come or they may be overt – such as when pickers on a disposal site force their way into the site, insist on burning the waste or threaten drivers who are bringing the waste. The habit of scattering unwanted waste when looking for recyclables has resulted in the banning and regular impoundment of the carts of informal recyclers in some places [Imam, 2007].

Informal sector waste workers may be opposed to change

- because they have not been consulted and fear that they will lose their livelihoods (especially the local "bosses" who control operations),
- because new collection proposals mean that they will lose access to the wastes or opportunities for additional paid work, or
- because they are being asked to change their way of working or location in a way that they think will make their work unprofitable.

c) Integration – There are various ways in which informal sector waste workers can be integrated into formal plans for upgrading a solid waste management system.

- One way is to employ them. In this case they are no longer in the informal sector, and others may start working in the informal sector to replace them. Labourers who have previously been in the informal sector may be reluctant to work in the formal sector if they thereby suffer a loss of income, if they object to working practices such as wearing uniforms and reporting at the same time each day, or if they prefer to work independently – to be their own bosses. In Cairo, Egypt, when a private company was contracted to provide a waste collection service, and was expecting to employ workers from among the informal sector "Zabaleen" community who had been providing a waste collection service for decades, it was found that the Zabaleen were not interested in working for this contractor as they were earning 2½ times the salaries offered under their original, informal arrangements. [Iskander, 2005].

- Another approach is to give them a defined role within the system. For example, they may be invited to collect waste from houses and shops (giving them an opportunity to separate for themselves items and materials that they wish to recycle) and transport the waste to transfer points. On disposal sites they may be allowed access to the waste for a few hours after it has been brought to the site and before heavy machinery is used to level and compact it. In both these cases, the management of the formal system needs to negotiate with representatives who can make decisions on behalf of the informal sector workers, and there should also be some form of penalty or sanction that can be used if the informal sector workers do not work in the agreed way. The formation of a co-operative may meet this need for providing a representative, but it may take a long time to get general involvement and support from among the informal sector workers, and an external facilitator is often needed to encourage informal sector workers to join together.

In many cities the informal sector is large, and solid waste management provides livelihoods to many families who would otherwise be destitute. Solid waste management is not just a technical issue, and an important part of the social aspect is the situation and role of the informal sector. They must be included in the planning process.

11.3.4 Factors to consider when planning refuse collection operations

If a change in the refuse collection method is being contemplated, it would be useful to discuss this with representatives of the informal sector. If no such representatives can be identified, it would be worthwhile to meet with some of the informal sector workers to inform them that changes are being planned and to indicate a willingness to discuss the arrangements that are being planned.

If a system of at-source segregation and separate collection is being considered, the informal sector waste pickers would be interested in the recyclables stream and, if containers of recyclables are left out, it is likely that they would take material from them before the arrival of the formal crews. It might be better to involve the informal sector in the collection of the dry or recyclables stream from the beginning.

If large containers are being provided as transfer points, it may be possible to allocate each street container to an informal sector individual, who would be allowed to take from it any wastes that (s)he wanted, provided that the surrounding area is kept clean. If (s)he does not keep the area clean, the right of picking would be given to someone else.

If the formal waste collection system expects householders to carry their waste to a shared container in the street, it might be appropriate to encourage informal sector workers to offer to collect waste from residents' doors, for a small fee, and take it to a street container. In this way employment would be generated and the collectors would have a chance to separate recyclable materials in a relatively clean state.

It is generally considered that using compactor trucks to collect wastes reduces the value of the recyclables in the waste, because the compaction pressure increases the contact between wet food waste and recyclable material, thereby contaminating the recyclables and reducing their value.

It is sometimes proposed that sorting should take place at transfer stations in order to recover recyclable material before it is transported to the disposal site. This has already been briefly discussed in Section 8.2.7 above. If informal sector workers are involved in sorting at a transfer station, there may be problems in controlling their work – especially ensuring that they work in a tidy way. It is therefore essential that they are organised in some way and have a manager who is responsible for them and can punish unacceptable behaviour.

The informal sector may control or influence where the collection trucks unload their waste. For example, at the Jam Chakro disposal site near Karachi, waste pickers rent plots on the site from an unofficial landlord, and pay drivers almost the equivalent of US$ 1 to deposit their loads on their plots [Rouse, 2006]. In other places force may be used to control the truck drivers.

11.4 INPUTS FROM NGOs AND COMMUNITY ORGANISATIONS

Good co-operation with the general public is essential for successful solid waste collection. A good non-governmental organisation (NGO) or community-based organisation (CBO) can provide very useful assistance in promoting co-operation.

NGOs often bring in experience from elsewhere, and if a particular NGO has had successful involvement in solid waste management in another city, it could prove useful to visit that city and evaluate the experience before requesting the help of the NGO. (Experience in community mobilisation in other fields in the particular city could also be of benefit.) The boundaries of the assistance required from the NGO should be clear, so that its members do not think that they are being asked to do more than is actually being requested.

CBOs are generally less specialised than NGOs and linked to one particular community. In most cases CBOs are likely to have little knowledge of solid waste management, so their value lies in their links with local people and officials and with their experience in promoting community involvement and participation. If there is no community organisation and no way of consulting the community, it can be worthwhile to establish one. Rahman [2003] provides an interesting account of the formation of a community committee to participate in the planning of a solid waste collection service, and the benefits that resulted. Consultation improves the chances that the system will be acceptable to the community. Community involvement can also be useful in monitoring and improving a collection system when it is in operation.

Summary points

- Even when the solid waste services are being provided by the private sector, national and local government has important roles that are essential to maintaining good standards.
- There are many ways in which the private sector can be involved; choices regarding the modality and extent of this involvement should be made with care.
- There are real benefits to be gained from pro-active efforts to inform the public and to consult them regarding issues that affect them.
- The informal sector can provide useful collection services and bring economic and environmental benefits from recycling. In many cities many families depend on informal sector recycling for their livelihoods. For these reasons the informal sector should be included in plans that might affect it.

12 MANAGEMENT OF THE WORKFORCE

Managing the labourers, drivers and mechanics who operate a waste collection service is one of the greatest challenges in solid waste collection. It requires a combination of many characteristics, including determination, hard work, honesty, firmness, fairness, compassion and patience. The tasks of management include planning, recruiting, training, supervision, disciplining, monitoring and reporting. This chapter does not attempt to cover all aspects of the task, but aims to highlight some key issues and outline the scope of the management function.

12.1 ORGANISATIONAL STRUCTURE

There are four main functions (that involve more than a few employees) that are directly involved in collecting solid waste: street cleaning, loading wastes into vehicles, driving, and vehicle maintenance. There are various ways of organising these four functions. Some of the issues to be considered when determining how they will be located in the organisational chart of the local administration are discussed in this section, under the headings of the various possible arrangements.

12.1.1 Loading and sweeping together

The combined number of sweepers and vehicle loaders in a big city can be very large – up to 0.5% of the population. In major cities it is clearly necessary to divide this workforce into smaller groups, according to districts which may be based on political boundaries (wards). Further subdivisions of the workforce are needed so that effective supervision can be provided. Because of the repetitive and sometimes unpleasant nature of the work, the area over which the labourers are scattered, and the fact that the labourers are seen every day by the public, it is essential that there is an effective system of supervision.

The number of manual labourers that one person can supervise depends on the type of work, the distance between their places of work, the means of transport that is used to travel between their places of work, the available means of communication (radio, mobile phones etc), and the intensity of supervision that is required. Different names can be used for the various levels in the supervision pyramid; Figure 12.1 shows one possible combination of job titles.

Should both sweepers and waste collectors in one district be under the same supervisor, or should these services be kept separate?

There are several advantages in having both services under the same command:

- A foreman can monitor both services in the same area.
- The collection from containers can be linked with sweeping duties so that a sweeper ensures that bins and containers that are lifted mechanically are ready for collection at the scheduled time. (Unless containers are

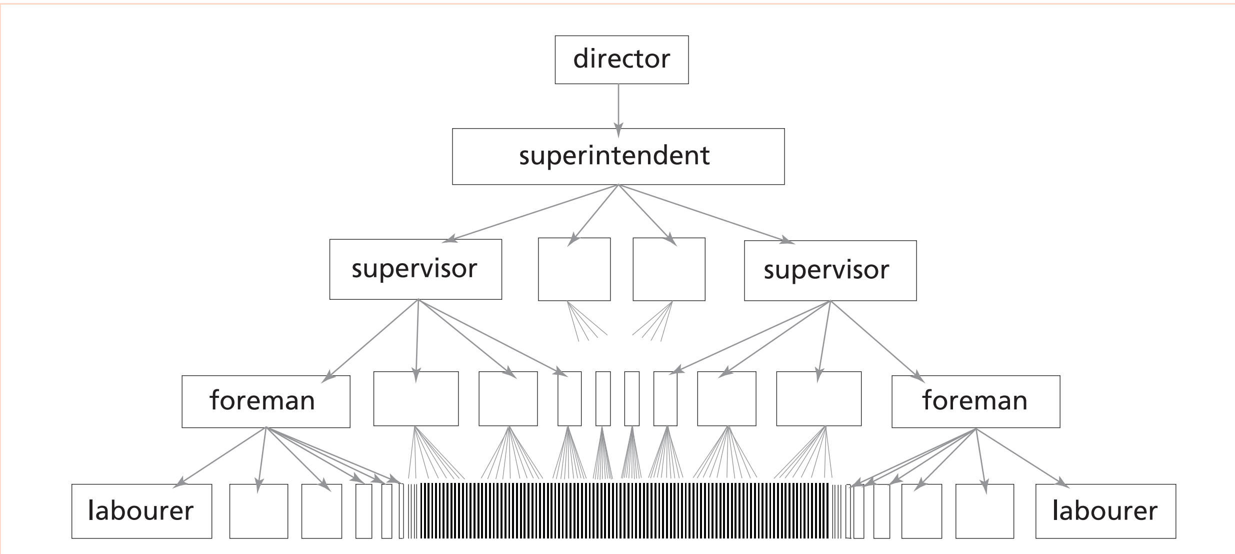


Figure 12.1 A typical supervision structure

overflowing, all the wastes lying around them should be put into the containers before the truck arrives.) When waste has been loaded from a container into a truck, the sweeper can ensure that any spilled waste is cleaned up, so that it is not necessary for the truck to wait while its crew clean the area.

- It may be possible to transfer staff between the two functions, for example transferring sweepers to waste collection to ensure that each truck has a full crew, or transferring some collection staff temporarily transferred to street sweeping when special events are expected to result in more street waste.

Combining the functions in this way assumes that the boundaries for the districts of the two services can be identical. This could be a problem if a new type of collection vehicle requires larger supervision districts.

12.1.2 Drivers with mechanics or loaders?

The way that a truck is driven can have a significant impact on the amount of maintenance work that it needs, so a workshop supervisor should have some control over the drivers, to be able to discipline or train them if they are using their vehicles in a way that requires additional maintenance. Drivers are generally required to make daily checks on their vehicles and report problems to the mechanics. If any faults are developed during the collection rounds the drivers should be directed by the workshop supervisor regarding what action is necessary. For all these reasons the drivers should be responsible to the management of the vehicle workshop.

However, there are also reasons why the drivers should be responsible to the same supervisor as the loaders. The driver must co-ordinate with the loading crew, so they should both be following the same orders. The driver can function as the foreman of the loaders. If the supervisor of collection operations has no authority to instruct the driver, then the supervisor may have little control over the work of the collection crew, since they must accompany the vehicle.

12.1.3 A separate waste management department

One solution to the dilemma as to who should have authority over the drivers is to form a waste management department that includes both the vehicle maintenance and the waste collection operations. Usually, most of the vehicles in a municipal garage are waste collection vehicles, so there is some justification for putting the workshop under the head of solid waste management. Other vehicles in the depot may include official cars, vacuum tankers for cleaning drains and emptying septic tanks, equipment for maintaining street lighting, and other vehicles, according to the responsibilities of the municipal administration. Should these other vehicles also be maintained by the solid waste management department, or should there be two separate vehicle workshops within the municipality?

A separate solid waste management department may be appropriate if there is a solid waste management fee that is to fund all solid waste management functions. In this case it may be decided to set up a separate department with its own independent accounts (Section 13.1.4).

An alternative to forming a separate department may be to improve co-ordination between the transportation (vehicle workshop) department and the solid waste management department, and develop agreed working rules regarding procedures in particular situations.

12.1.4 Public and private sectors

Although it does not feature on an organisation chart, aspects of co-ordination with private sector partners must be carefully considered when contracts are being prepared. There are many ways in which the private sector may be involved. Examples are a private operator providing vehicles which are loaded by municipal crews, or providing drivers and crews to man vehicles that are owned by the municipality, or providing one component in a two-stage (primary collection, transfer and secondary transport) collection system. There is a wide range of possible interrelationships. Issues of control and authority must be clearly described in the contract documents and understood by both parties. Section 11.2 discusses the participation of the private sector in more detail.

12.2 PLANNING

In most cases a public sector manager is not able to plan the size and deployment of the staff, because when a person is appointed manager, the workforce is already employed and there are restrictions on dismissing workers and reducing the size of the workforce. In many cases labourers have been appointed as a personal favour or for political reasons. Sometimes appointment as a waste collection labourer is seen as a social safety net to provide an income for those in need. Working as a labourer in waste collection may be seen as the lowest form of work, to which unskilled labourers are appointed if they are not able to do any other work. Many of the loaders may be too old for the physical demands of loading waste. Nevertheless, the manager should try to gain control of the numbers of employees and to exert increasing influence on recruitment.

Taking control of the size and deployment of the workforce can be seen as an issue of political will. If decision-makers wish to reduce the costs of waste collection and increase coverage, it may be necessary to take unpopular decisions regarding the management of the workforce. Such decisions could involve freezing recruitment, transferring older staff to tasks that are less physically demanding, dismissing staff whose work habits are unacceptable, and increasing the amount of work (such as the length of street to be swept) that is expected to be completed in one shift.

Another issue which often has political repercussions is the employment of temporary (or daily-waged) staff to replace permanent employees. Permanent employees often have very advantageous employment conditions, including pensions, sick pay and various allowances, and it can be very difficult to dismiss them, even if their work is clearly inadequate. Temporary staff are usually less expensive and can be expected to work harder in the right conditions. Some argue that such workers are exploited while others say that they are free to choose and would not take the job if they could get better pay and working conditions elsewhere. Labour unions in particular may oppose the employing of temporary staff if most of their members are permanent employees.

Freezing recruitment of permanent staff can be an effective way of reducing the size of a workforce (though there are cases where the law requires that a son or daughter of an employee should be given a job if the employee retires on grounds of ill-health – and the definition of "ill-heath" tends to be very broad). Since most cities in developing countries are increasing rapidly in size, the increase in waste generation can be covered by employing temporary staff or engaging private sector operators.

Planning the optimum size of the workforce requires a knowledge of a reasonable level of productivity for each category of labourer. Examples are the length of street that can be swept in one shift and the number of trips that a collection vehicle can make in one day, coupled with the optimum number of loaders working with a vehicle. (Labour unions may have norms that they insist on, such as the case in which six labourers were required to work with a container hoist truck that needed at most one labourer [Coad, 1997]) Determining a reasonable workload for each type of work can be done by using work study (or time and motion) techniques (Annex A1), provided that the rate of working that is being observed and recorded is neither excessively high or unacceptably low.

Strikes by waste collection workers are usually very effective because of the immediate effect on city streets of accumulations of uncollected waste. The power of the labour unions that represent waste collection workers can be a serious obstacle to making changes in the workforce or in working practices. Unions can be particularly strong when street sweeping and loading are regarded as jobs that are only done by members of a minority ethnic group, and when the unions are strongly linked to that group. It is essential to involve unions in any discussions about changes that will affect their members. Union officials often show a sense of responsibility and a readiness to be reasonable. In difficult confrontations it may be useful to appeal for the support of public opinion, such as exposing unreasonable pay demands and linking them to increases in fees.

Some difficult issues may be raised if it is decided to transfer waste collection completely, or even partly, to the private sector. In most cases this will mean changes for a large number of manual workers. As municipal employees, waste management workers usually receive additional allowances, sick leave and sick pay, medical insurance and pensions. If they transfer to the private sector they may get none of these additional benefits, and they may be required to work longer hours each day. Municipal employees who have been expecting secure employment and these benefits may be unwilling to surrender them, and they may have the support of the law. It is not surprising that they oppose any pressure to leave municipal employment for the private sector. It is often the case that the municipality is unwilling or unable to keep them, perhaps because there is no work for them or no money to pay their wages, since the funding that paid their wages is now going to the contractor who has taken over their work. As a result, contracts often include the obligation on the contractor to take at least a proportion of the municipal waste management staff. However, the contractor may be unwilling to take on the municipal staff, because he regards the working habits of municipal staff as incompatible with the higher productivity required in the private sector and wishes to have a lean and muscular workforce – fewer people working harder. Solutions to these problems can be found, but they need careful preparation and good planning.

12.3 ALLOCATION OF DUTIES

The deployment of staff to work in particular places is another issue that can provoke opposition.

In cities it is usual for street sweepers and loaders to report to district offices or muster stations at the beginning and end of each shift. To reduce travel time and costs, employees should, to the greatest possible extent, be required to report to offices close to where they live. There is usually a roll call at the start and end of each shift, and instructions are given to the labourers so that they know where they should work or which truck crew they should join.

There are some advantages in sending street sweepers and collection crews to work in the same areas each day. This enables them to become familiar with the geography of the area – where the bins are kept, who needs reminders to put out their waste, which streets should be swept first before many cars are parked there etc – and so provide a better or more efficient service. This also enables them to build up a relationship with the residents or shopkeepers, so that the cleaning workers can ask for better use of containers and perhaps later encourage at-source segregation. The collector or sweeper may also benefit from gifts of used clothing and unsolicited cash gifts at festival times.

There can be advantages in combining services in one neighbourhood and making one employee responsible for that area. This responsibility, coupled with the relationship with the residents and shopkeepers, can lead to the labourer feeling a sense of ownership for the area and a pride in doing work well. This was observed in a city in Iran where primary waste collection, street sweeping, drain cleaning and irrigation of roadside trees, all in one neighbourhood, were the responsibility of one man.

There is a potential drawback from long-term relationships between street sweepers and residents. This is illustrated by an observation that in Karachi street sweepers buy and sell the right to work in certain areas where they can find extra work for residents, such as sweeping their yards [Ali, 2001]. There is no problem with this if they do this private work in their own time, but if they do it when they should be sweeping the streets, the municipal management has a right to be concerned. Clearly, the sweepers who have paid informally for the right to work in a particular area would not be pleased if they were ordered to work elsewhere.

Certain work locations may be more popular than others. The possibility of getting additional private work has been discussed, but sweepers and waste collectors may prefer to work in certain areas where they are given refreshments or tips, or where there are more recyclables in the waste, enabling them to make additional income by selling these materials. Some collection routes may be shorter or quicker or involve less walking than others, and be preferred for these reasons. Emptying of fixed bins and enclosures is more difficult and unpleasant than loading plastic sacks, and high-sided open trucks are more difficult to load than rear-loading compactors. Because of these differences, the assignment of duties can be used as a mechanism of reward or punishment. Phang, [1996] described how transfer to a more distant location or a less popular route has been used to discipline collection labourers who were not performing satisfactorily.

In general, it is desirable to equalise the workloads of individuals and collection crews as much as possible. More difficult or unpleasant tasks could be compensated by shorter working hours or bonus payments.

12.4 DEFINING TASKS

In most cities there are wide variations in housing density and layout, and so the tasks of collecting wastes from these different areas cannot be identical. These variations pose a challenge to the manager who is trying to ensure that the workloads for all staff are equivalent, and also to find ways of motivating the workforce.

There are three main approaches for defining the work that a waste collection crew is expected to complete in one shift;

- **Timing** – the crews are instructed to stop collecting at a certain time and take whatever they have collected to the disposal site. This method ensures that all teams work for approximately the same time, and may cause congestion at the disposal site as the end of the shift approaches. It does not encourage the crews to work hard. In theory it would be possible to link this approach to the weight of waste that is collected, and penalise crews if they do not collect at least a minimum amount of waste, but in practice it is usually difficult for a municipal administration to penalise its employees, and the weight of a load can be increased by adding water, rocks or construction debris.
- **Number of trips** – each crew may be required to complete a given number of trips (often, two) before returning to the depot. Again the difficulty is that the truck may not be fully loaded. A case is reported in Scheu [1994] in which a crew that was intending to go

to the disposal site decided, when they learned that the load was to be weighed, to continue loading, and added an estimated 60% to the load on their truck before considering their loading work completed and driving to the disposal site. Clearly there are different ways of defining a full load!

- **"Task and finish"** – Each collection crew is given a work assignment (a list of bins to be emptied or houses to be served) which can be completed within the time available if they work at a reasonable rate. When the defined task has been completed they are free to go home. This has the advantages of motivating the crew to work hard and in enabling the collection area to be divided between the routes with the expectation that each of the routes will be fully covered on the planned days. It does, however, require a significant amount of work to define each route, in order to ensure that each team has a task that requires about the same amount of time and effort. There are also risks that teams will "cut corners" in order to finish early (for example not replacing bins in the right places, or leaving scattered waste) and continue to use a vehicle that is unsafe or defective rather than lose time by returning it to the depot and exchanging it for a roadworthy vehicle. A collection team may be unwilling to help another team which has encountered unforeseen difficulties, such as a vehicle malfunction.

  If any crew complains that their task is too big – perhaps because of traffic congestion, newly constructed housing or errors in the initial task definition, the management must be ready to investigate their claim by observing them in action as they go on their round. Similarly, if one team always comes in very early, it may be because they are working very quickly or they do not work properly, or because the task that they have been assigned is smaller than the others. This might be checked by either observing the team in action or changing crews (but not, perhaps, the drivers who know their own routes well) to determine whether another crew can work as quickly.

If the collection system uses wheeled bins or similar containers that are emptied mechanically, consideration should be given to defining the action that should be taken if a container is overflowing or if there is a considerable amount of waste around the container. If the loading crew working with a truck is required to clean up all the scattered waste, the truck will be idle for some time while this is being done. For an economical service, the truck should be working (either travelling or loading) for the highest possible percentage of the time, so waiting while spilled or scattered waste is cleaned up may be an expensive option. Furthermore, if more time is spent in cleaning up scattered waste, the truck is able to empty fewer containers in a shift, and so other containers are not emptied at the intended frequency and are therefore more likely to be overflowing when they are eventually emptied, causing further delays and so on – a vicious spiral. In such cases it may be more cost effective to provide more containers or to employ more sweepers – either based near the containers or following each truck route on a bicycle – to sweep up the scattered waste before and after the containers are emptied.

A common shortcoming among solid waste managers is the failure to use simple mathematics to calculate the cost implications of the decisions they make. Management decisions should be based on calculations of unit costs (costs per ton or costs per household) or productivities (tons collected per loader or per vehicle). These calculations can be done by hand using a pocket calculator, but the use of spreadsheet software on a computer facilitates repeated calculations as the effects of the changes of one or more variables are investigated. The data that are used in these calculations must be reliable and reasonably accurate, but with a little practice in work study techniques, useful field measurements can be made by observing collection crews at work. Annex A3 provides an example of this type of calculation, and further examples of calculations made with a simple spreadsheet program, and how the results can be used, have been reported by Coad [1997]. The expenditure involved in employing someone to monitor cost implications in this way is likely to be much less than the savings in operation costs – and it is easily possible to check if this is true by estimating cost savings and comparing them to the salary of the person who is estimating unit costs and productivities. If the savings resulting from their work are less that their salary, they can be transferred to other work. It may even be possible to interest a postgraduate student in doing such work as a research project, at no cost.

12.5 HEALTH AND SAFETY

Waste collection is a dangerous occupation. There are many kinds of risks of infection and injury. Prevention of illness and injury is not just a humanitarian duty and an employer's responsibility, but can also improve morale and motivation, reduce costs and improve service reliability. In the context of waste collection, consideration should be given to the following aspects:

- The design of the equipment. Containers, tools and handcarts should be designed and maintained so that they are efficient in use but do not require excessive amounts of effort to lift or push. They should also be free of sharp edges. Particular attention should be paid to ensuring that containers that are lifted mechanically cannot fall and cause injury. Consideration should also be given to road safety – there are tricycles that do not allow the operator to see where he is going when they are fully loaded, and wheeled containers that must be pulled by a labourer walking into the middle of a street. Some simple vehicles may be difficult to see at night.
- Protective clothing should be selected with care so that it is sufficiently comfortable to wear and contributes usefully to the safety of the wearer. Gloves, boots and face masks should be provided if the workers can be persuaded to wear them. Too often safety clothing is not worn, but it may often be for good reasons (such as the discomfort caused by wearing impermeable gloves for a long time, or the difficulty of picking up small items while wearing thick gloves). Bright colours should be worn by labourers during the day and reflective waistcoats or similar garments at night.
- Toilets, washing facilities and changing rooms should be provided where they are needed, and kept in clean condition. The importance of handwashing should be stressed.
- Immunisation and regular medical checkups are important ways of protecting the health of the workforce.
- All accidents and any incidents that might have led to injury should be investigated. This requires a management style that values learning much more than blaming.
- Loading waste is physically demanding. Older employees should be transferred to work that is less strenuous, such as street sweeping. Loaders should never be expected to lift wastes above their shoulder height because excessive loading heights result in wastes falling on their heads increasing the risk of contracting disease. Loaders standing on wastes in the trucks are at serious risk of infection.
- Training is essential so that waste collection workers understand the origins of the risks that they face and know how to minimise these risks. However training often has little impact unless it is reinforced by supervision. These two aspects are discussed in the next sections.

Health and safety should become part of the culture of every solid waste management organisation, and this requires leadership and effort from the top.

12.6 GENDER ASPECTS

In many developing countries the roles that are available to men and women are clearly defined. It is common to find that street sweeping is done by both men and women, but the loading of trucks is done only by men in many places, and only by women in some countries, such as Vietnam (Photo 12.1). In Bangladesh boys are employed to collect waste door-to-door because men would not be allowed into the yards of private houses. Usually vehicles other than handcarts are driven or operated by men. Some community-based enterprises involved in collection and street sweeping in Dar es Salaam are managed by women and others by men. In some countries the collection of recyclables is done by both men and women, and in others it is divided up according to the materials that are collected – only men collect metals for example. In Vietnam, street sweeping is usually done at night, and this can be a disadvantage for women, because of the risk of harassment.

An important task in solid waste management is to inform the residents about services and developments and to educate them regarding their environmental responsibilities. Since women and children are more involved with waste than men, it is essential that women are employed to pass on the information and ideas to women and children. Visiting women in their homes has proved to be effective, though this method is also very time-consuming.

A successful method of monitoring the work of waste management contractors was pilot tested in Aswan, Upper Egypt. Women were engaged and trained to observe

Photo 12.1 Women loading a truck while the male driver relaxes

waste collection operations in their own neighbourhoods, and report their observations each afternoon. They also reported on other infrastructural needs of their areas. Because of their identification with the neighbourhoods where they were working, it is believed that they would be more conscientious than the alternative – male inspectors from other districts.

Women are generally preferred to men for employment in departments that handle complaints.

Whilst in industrialised countries women can be found in all aspects of waste management, gender roles appear to be more defined in the developing world. This latter case may be because manual labourers tend to be more conservative, but it may also be due to the hard physical work that some tasks require.

12.7 TRAINING

Training of workers at all levels is an essential part of a successful solid waste collection system.

12.7.1 Training manual workers

Manual workers need training in

- safe working practices – lifting, avoiding inhaling dust, crossing roads, safety when using hydraulic lifting or loading equipment, use of safety and protective clothing, procedures for assisting drivers to reverse vehicles safely, etc.
- working policies, such as the types of waste that can be collected,
- personal hygiene and basic first aid, and
- dealing with the public, especially explaining to angry citizens how they can make a formal complaint.

All manual employees need to be familiar with this basic information. Since it is not possible to give this training to temporary staff in the morning when they are asked to start work, there should be a pool of temporary workers who have already taken the training and who can be called upon to make up numbers of sweepers and loaders at short notice.

Employees who have been working in waste management for a long time may never have had training on these topics. It would be worthwhile to provide them with this training also, and provide refresher courses at regular intervals.

It is desirable that the staff who have attended such training sessions are tested to indicate what they have remembered and understood. Since they may be illiterate, a written test would not be appropriate. It would, however, be possible to give a multiple choice test based on a video presentation. Otherwise the trainees could be interviewed or given an oral exam.

12.7.2 Training drivers

Drivers should participate in the same training courses as manual workers, but they also need additional information, including

- performing daily vehicle checks and what to do if any deficiencies are detected
- driving in ways that do not cause unusual wear and tear
- safe reversing procedures
- driving on soft ground (if delivering waste to a disposal site)
- what to do in the event of a breakdown, accident or puncture
- use of communications equipment (if any), and
- first aid.

In some cases drivers are also responsible as foremen for the operation of the collection crew that they work with. To prepare them for this additional responsibility they would also need training on their own rights and obligations, and those of their team members, and requirements related to reporting.

12.7.3 Training for mechanics, electricians and skilled tradesman

The training for these trades in vocational schools can be of variable quality so it is often necessary to rely on "on-the-job training". Unfortunately this is often taken to mean fetching tools and watching the "trainer" rather than supervised "hands on" experience. Training provided by manufacturers when new types of equipment are acquired should be given to the employees who need it and will use it. If the training is overseas, it sometimes happens that the wrong people are sent because the opportunity for overseas travel is seen as a reward.

12.7.4 Training for managers, engineers and technicians

Because of the many differences between solid waste management in industrialised countries and developing countries, it is important that professional training is appropriate to the conditions that the trainees are working in (see Section 1.3). Training that is suited to industrialised countries where the waste characteristics are very different can result in the selection of inappropriate (and therefore inefficient and ineffective) equipment and a serious waste of money.

Training should build the self-confidence – as well as the knowledge of the trainees – so that they are able to argue against any unsuitable proposals that might be made by visiting international consultants regarding the selection of equipment and the design of collection systems. Furthermore, the training should not focus only on design and planning, but should contain a large proportion of practical guidance on managing, operating and maintaining systems, and getting the best possible performance from the workforce. An additional, important aspect should be to present a sociological perspective, to persuade managers of the benefits of greater public awareness and a higher degree of public participation.

Training courses are only one source of professional knowledge, and they are likely to have more impact on the amount of information a person has than on the way they do their work. Much can be learned from a superior or colleague who sets a good example and is ready to answer any questions – even questions that some might consider to be "stupid". Useful practical knowledge can be gained from meetings of peers, and for this reason professional associations can be very valuable – provided that staff are released to attend them. The transfer of useful information is much greater if all who are involved are ready to accept and admit to mistakes, disappointments and failures. If all initiatives and endeavours are presented as complete successes (when they were not), the flow of useful information is stifled.

Training courses alone rarely change behaviour. When coupled with supervision and follow-up the effect can be much greater.

12.8 SUPERVISION

Supervision is needed for increasing safety and efficiency, and for promoting good public relations.

12.8.1 Safety

All drivers and manual staff should have participated in training on safety issues, but this does not guarantee that they will always practice what they have been told about. They may have forgotten much of what they were taught or they may be unwilling to follow instructions for a variety of reasons. Supervision is needed to reinforce the training.

Many of the risks faced by waste collection labourers are associated with vehicles – traffic accidents when crossing roads, accidents to staff or the public when vehicles are reversing, and accidents involving hydraulic equipment on collection trucks. Supervisors must be alert to such risks and treat as serious any behaviour that is likely to increase such risks. The issue of protective clothing is relevant here. Labourers working on streets should always wear high visibility waistcoats or jackets and strong shoes. Other requirements should be carefully considered. The wearing of gloves throughout the working day appears to be advisable, but some types of glove are very uncomfortable if worn for long periods and may even cause skin problems. The selection of a suitable type of glove should involve negotiation and compromise to ensure that the type that is chosen is acceptable to those who should use them while affording at least some degree of protection. Whilst the wearing of dust masks may be beneficial, most manual labourers are unwilling to wear them for long periods. As much as possible, loading methods should be designed so that labourers have the minimum contact with dust and fungal spores.

Procedures used for reversing vehicles, particularly on disposal sites, should be strictly enforced by supervisors. This is a common cause of accidents, particularly as waste pickers often jump onto trucks before they stop and try to get the first access to the waste when it is unloaded. Loaders should be regularly reminded by their foremen of the dangers associated with the loading mechanisms of compactor trucks.

12.8.2 Efficiency

It is unfortunately true that the working habits of loaders and sweepers are often characterised by slow speed, long breaks and a short working shifts. Ways of motivating truck crews are necessary. Whilst incidences of gross carelessness, negligence or aggression can be punished, it is difficult to punish widespread and endemic laziness. Crews may be motivated by the "task and finish" system (Section 12.4), competitions (though it is difficult to compare performance when each collection route is different) and the fear of being moved to a less popular route (Section 12.3). There might be some benefit in basing a bonus on the results of a regular customer satisfaction survey, but it is often difficult to award bonuses in the public sector because of regulations, and bonuses often gradually change into an expected and regular payment, losing their impact.

Drivers, mechanics and clerical workers, whose jobs require them to fill in forms and keep log books and other records, may be encouraged to report accurately if they know that a manager is checking their records and responding to what is written in them. Conversely, if they believe that no-one looks at their records and reports, they are likely to feel that these documents have no value and so they become careless in reporting.

Mechanics may be motivated by monthly statistics that summarise their performance, expressed perhaps as the average number of days taken to repair a vehicle or the total number of vehicle-days lost because of repairs and maintenance. However, if the delays in repairing vehicles are caused by factors outside their control, such as the lack of spare parts, such information will have no motivational effect. A system for calculating additional "out-of-service" costs caused by delays in completing maintenance assignments, and allocating these costs against the person responsible, is described in Annex A2. This can help to make employees and managers realise how any inadequate performance on their part contributes to waste management costs. Drivers may be motivated if they are always driving the same vehicle and if the number of days since their last accident or breakdown is displayed – though this may discourage them from reporting accidents.

Background factors can also help to create or destroy motivation. An active management, that shares information, works hard to ensure that vehicles are kept in good condition, and listens to employees' concerns and suggestions, is more likely to have a motivated workforce than a casual and ineffective organisation. Efforts should be made to elevate the status of waste management workers in their own eyes and in the eyes of the public.

Motivation and efficiency may increase when payrolls, attendance records and active participation are checked. Some large waste management departments have on their payrolls "ghost workers" who do not actually exist. Perhaps the names belong to former staff who have since retired or died. Because of these "ghosts" someone is getting paid for doing no work. There may also be labourers who sign on or respond to a roll call (or get a friend to do this on his behalf) but who do not do any work. Foremen who do not report such absences should be disciplined. Team members who do not work have a disproportionate effect of the output of their team because they discourage others from working. Again, the foreman is required to take action here.

12.8.3 Public relations

Residents and shopkeepers can play an important role in supervising those solid waste management operations that take place in urban areas. (For example, they may be asked to monitor the use of a street container near their premises and report any problems.) To benefit from this opportunity, waste management organisations must take definite steps to build bridges to the public.

Pro-active steps include training all staff in how to speak to members of the public, presenting a good image by means of the appearance of the staff (clean uniforms) and vehicles (even handcarts should be painted, clean and in good condition) and by taking the initiative to publicise progress and achievements in the popular media.

The main responsive step is to deal with complaints quickly and effectively, keeping the person who made the complaint informed about action that is taken in response to their complaint. Complaints – and compliments – from the public should be encouraged. Each employee should be required to wear an identification badge at all times so that people who make complaints can identify individuals who are guilty of misconduct. Supervisors are often involved in visiting residents and shopkeepers who have made complaints, and this personal contact should be valued as a means of building positive relationships with members of the public. Complaints can be used to guide supervisors and inspectors regarding where they should concentrate their efforts.

12.8.4 Other comments regarding supervision

Transportation and communication are two key factors that have a big influence on the effectiveness of foremen and supervisors. Even a bicycle can make a great difference to the number of sweepers that a foreman can be responsible for. (In Mumbai there was a foreman for each vehicle crew and he travelled with the truck [Scheu, 1994]. The lack of independence of the foreman and his close relationship with the crew may have made if difficult for him to give and enforce instructions that were against the wishes and opinions of the crew.) A mobile phone can be a great asset for informing foremen and supervisors about situations that need their attention. Sometimes mobile phones are restricted so that they can only be used to dial certain numbers; in this way phones that are issued for official business cannot be used to make personal calls. Two-way radios are also used, but they are expensive and so may be issued only to senior operations staff.

It is common for loaders to separate recyclable items from the waste as they are loading a truck, and sell the items that they recover to dealers at the disposal site. This is a widespread practice in spite of the fact that the crews are instructed not to do it. Rather than seeking to impose a rule that is very rarely obeyed, it might be better to negotiate a method of separating recyclables that causes the least delay to the collection operation.

Another common regulation that is difficult to enforce is the prohibition on asking householders and shopkeepers for tips. If this regulation is to be strictly upheld, the public should be informed about it and asked to notify the solid waste management department if they are asked for extra payments.

There is great benefit in observing operations and seeing the difficulties that are faced by the street sweepers and waste collectors. Supervisors and foremen can be the eyes of the department, provided that they are encouraged to look for ways of improving the safety, efficiency and public image of the work, that they have regular meetings with the management and that the management is ready to listen and act on what they have to say.

Summary points

- Because of the size of the workforce, low levels of literacy and the low status of the work, the challenges posed by management of workforce are perhaps greater in solid waste management than in other services. Motivation and efficiency are the goals.
- Unsuitable organisational arrangements can have a serious impact on performance.
- The members of the public (who are also the customers and electorate) are very aware of any shortcomings in the collection service. Public relations is an aspect of the manager's responsibilities which is often neglected.
- Solid waste collection is a hazardous occupation, posing risks to health and from traffic accidents and lifting. Training and supervision can help to reduce the risks.

A1 COLLECTING DATA ON WASTE COLLECTION OPERATIONS

A1.1 WHY ARE OPERATIONAL DATA NEEDED?

When reading proposals and consultants' reports that are concerned with improving waste collection systems, it often appears that most effort in data collection is focussed on household surveys of waste quantity and composition. Furthermore it seems that often these waste composition data have very little impact on the final recommendations. This observation leads to the conclusion that, when planning data collection, it is important to first consider the way in which the data will be used so that (i) the most appropriate method of data collection (including location and degree of accuracy) can be determined, and (ii) time and resources are not wasted in the collection of data that do not have a significant influence on the outcomes and designs. The importance of waste density data, and guidelines on the collection of waste generation and density data, have already been discussed in Section 3.2. In addition to collecting relevant and reliable information on the local waste density and quantities, it is often important to collect data on waste collection operations.

Data on waste collection operations are concerned with costs and working rates or productivity[45]. This information may be used for a number of purposes, including,

- **Evaluating the current system** – This may be necessary in order to look for ways of improving the efficiency of the present method and organisation of waste collection. This might involve modifying the collection methods that are used, increasing the proportion of the time that the loading crews are working productively, or investigating the effects of changing the working hours, the size of the crew, or the number of shifts worked per day.
- **Extending the current system** – In order to estimate the resources that would be needed to extend the collection service to new areas it may be necessary to know the average working rates and travel speeds that are currently being achieved.
- **Determining the assignment for each crew** – Each vehicle with its crew is given an area to collect from, and each area has different characteristics, such as different types of housing, different problems regarding access, and different distances to cover. There may also be different methods of collection used in different parts of a city. In order to divide up the work of collecting waste from an entire city between the crews and vehicles in an equitable way and to maximise the productivities of both vehicles and labour, there must be operational information regarding the work involved in each district.
- **Comparing alternative proposed systems** – This book has shown clearly that there are many possible waste collection systems, and different types of storage container, transportation and transfer station concept that should be considered when a new system is being proposed. In most locations there may be several possible combinations of organisation and equipment that are feasible and appropriate. The best way of comparing these options and selecting the best includes a comparison of the unit cost of each, as illustrated in Annex A3. A wide range of data is needed to estimate the times, productivities and costs with sufficient accuracy for such a comparison, especially when there is no local experience of some of the systems that are being proposed. It may be possible to collect data from other cities that are using the particular equipment or system, or it may be possible to operate a new system for a short time on a trial basis. If estimates that are not based on field observations are used for calculating costs, it is advisable to investigate the influence of varying the value of such estimates on the final result, so that more care can be given to estimating the data that have a major impact on the final unit cost. As discussed in Annex A3, a simple computer model is very useful for determining the impact of a change in any input variable in a sensitivity analysis.
- **Designing a new system** – When the best option has been selected it is necessary to design it in detail, considering a wide range of parameters relating to the specification of equipment, the deployment of manpower and the location. Before the detailed design of the system is finalised, it is advisable to operate the proposed system on a small scale, using one or two vehicles to collect operational data and check assumptions that have been made at the design stage. The detailed design of a system includes the size and profile

45. *In connection with waste management, productivity usually means the amount of waste (weight or volume) that is handled by one person or one machine in a certain time.*

of the workforce, types, sizes, numbers and locations of containers, the types, sizes and numbers of the various kinds of vehicles, the location, type, size and design of transfer points or stations, and the division of the area and generators to be served into work allocations for each vehicle and team.

The collection of data on speeds and productivities is known as *work study* (also known as *time and motion study*). As mentioned in Section 9.1, work study can be divided into two aspects – method study and work measurement. Box A1.1 provides some practical guidance regarding the collection of work study data.

The remainder of this Annex is divided into three sections. Section A1.2 lists the types of information that may be collected in a work study exercise. The following section mentions other types of data that are useful in planning and monitoring operations. Finally, Section A1.4 lists many of the ways in which operational data can be used.

A1.2 GUIDELINES FOR A WORK STUDY SURVEY

The data that are collected in this type of survey can be used to assess the efficiency of the existing collection service and provide the capital and operating cost data (labour, fuel and maintenance) for different collection and transfer alternatives to be considered. The procedure that is outlined here can be repeated for the different types of vehicles currently in use and for different collection areas. The following list suggests the information that might be collected and provides explanations of the significance of the information. The selection of the information that is collected depends on the purpose of the work study and the system being studied.

a) The make and fleet number (or registration number) of the truck to be studied. This is the link to the vehicle records that give detailed information about the vehicle, including its estimated economic life and cost, and its size and type.
b) The loading height. This should be measured with a tape measure. It is an important feature of a waste collection truck which may not be shown on the vehicle specification. The loading height affects the rate of loading of a truck, and also has implications for the health of the loaders (see Photo 7.10).
c) It is often important to know the volume of the load-carrying part of the body. It is generally easy to measure the dimensions of non-compacting bodies using a tape measure and to calculate their volumes,

Box A1.1 Additional information

Some tips about collecting work study data

Most work study data are collected by watching people working. It is generally not possible to observe them working without their being aware that they are being watched. (If employees are being watched without being aware of it, and they later find out that they have been observed in this way, this may create an atmosphere of mistrust and problems for the management.) Therefore it is necessary to inform the employees who will be observed regarding the purpose of the work study and to get their agreement to participation in the exercise. If the employees are members of a trade union, it is important to discuss the exercise with the union leaders so that they will encourage their members to participate.

The data that are collected should reflect a way of working that is reasonable. Sometimes labourers may work at a very high rate when they are being watched because they fear that otherwise they might lose their jobs because they are considered to be lazy or unable to do the work. In other circumstances employees might work more slowly than usual, because they understand that their performance when they are being observed will determine how much work they will be required to do in future, and that a low productivity in the work study exercise will result in less work in the coming years. In order to compensate for these tendencies, it may be necessary to adjust the figures that are collected so that they reflect a reasonable rate of working. It may also be possible to check with operations records of previous weeks (using the landfill log book, for example, to show the number of trips achieved each day by the particular crews and the amount of waste collected) to indicate whether the rate of working that was observed was typical.

As with other data collection exercises, it is important to consider what items of information are needed, so that time and effort are not wasted on collecting information which is of no use. Recording operations of a waste collection crew can be very intensive at times, and so there may not be enough time to record information on all aspects of the work. It is useful to regard the first day's observations as a practice, so that techniques and the forms used for recording data can be improved to suit the particular way of working and local conditions. In some cases it may be useful to be accompanied by someone with a camera to photograph operational difficulties and working methods, and perhaps also the extent to which containers and vehicles are filled.

The observer should interact with the crew as little as possible. Instructions to the crew should only be given in the case of a serious risk of accident. In some cases it may be necessary to direct the driver to a weighbridge (at the end of the collection stage so that the amount collected is typical). However, it may be useful, at the end of the shift (avoiding causing delays that would affect the observed times) to ask the loaders and driver for their suggestions about improving the method of working, and their reasons for doing particular tasks in the ways that were observed.

but the volume of compactor trucks is more difficult to determine because the space taken up by the compaction mechanism and the ejector plate must be deducted from the gross body volume (Figure 7.36).

d) Fuel consumption. Measuring the fuel consumption using the fuel gauge in the cab is not sufficiently accurate, so the best procedure is to fill the tank to the top, and record how much fuel is dispensed from the fuel station pump at the end of the shift to return the fuel to the same level in the tank. Reliable information about fuel consumption is useful not only for calculating costs, but also for checking on theft of fuel by drivers or transport depot staff. Fuel consumption can also give some indication of the condition of the engine and of driving habits.

e) Note the kilometres recorded on the odometer for the truck being studied. In some cities it is found that the odometers are frequently not operating. Whilst this might be due to wear and tear, it is also possible that the odometers are disconnected or damaged deliberately so that fuel can be siphoned out of the tank and sold with less chance of detection, because is it not possible to link fuel demands to distance covered. The distance covered in a collection round is needed for calculating average speeds which are used when planning collection from other areas where distances are significantly different.

f) Note the time that the shift starts and the time that the truck actually leaves the truck depot. The truck may pick up its crew before it leaves the depot or drive to a muster station or district office to pick up the crew or receive instructions. Note any reasons for any delays in departure (such as waiting for the crew, refuelling or getting approval from the supervisor). The impacts of such delays on costs can later be investigated.

g) Note the crew size. The employees that accompany the driver may all have the same roles. Alternatively one may be a foreman, another may be responsible for operating the loading mechanism etc. During the shift it may be appropriate to count the crew from time to time to check that they are all working all the time.

h) Does each truck have its own supervisor? If not how many trucks is the supervisor responsible for? The cost of supervision should be included in the calculation of costs. It may be appropriate to note some observations of the way the supervisor works.

i) Note the time of arrival at the first pick-up point and note the odometer reading when loading starts. (The average speed of the vehicle may be considered to have three different values – (a) when travelling from the depot to the collection area and other movements within the urban area, (b) when travelling from one collection point to another, and (c) travelling outside the urban area to the disposal site.)

j) For some purposes it may be useful to record the time when the truck stops at each collection point and when it leaves. It may also be useful to record an estimation of the amount of waste that is loaded at each point, perhaps by counting plastic bags or noting how full the community containers are.

k) Observe and time the crew's activities – loading, looking for recyclables, taking breaks, talking to the public, etc. When the truck is being loaded, note if all the crew are actively working or if they are often obstructing each other. Note the different tasks that are involved in loading the truck and see how they are shared between the loaders (for example, with an open truck, is it always the same person who is standing in the truck to receive waste and distribute it?). Note any risks to health or safety that could be avoided. This information may indicate whether a larger or a smaller crew would be more efficient.

l) Note how the crew travel between collection points and the risks that they face – either in the event of a traffic accident or from contact with the waste. Do they ride in the cab or crew compartment, on small platforms at the back of the truck, or on the waste?

m) When the last load has been put into the truck, note the distance travelled (odometer reading) and the time and estimate the volume in the truck. Is the truck carrying its full load capacity or is it overloaded? (It is quite difficult to measure the volume of a heaped load. If the shape of the top of the waste is fairly regular, and the surface from the lowest point to the highest point is close to being a straight line, the volume of the waste can be estimated by considering that if the top surface were made horizontal the height would be one third of

If the *slope* of the top surface of the waste is fairly uniform, the volume can be estimated by assuming the waste can be levelled to the height given by x = y/3.

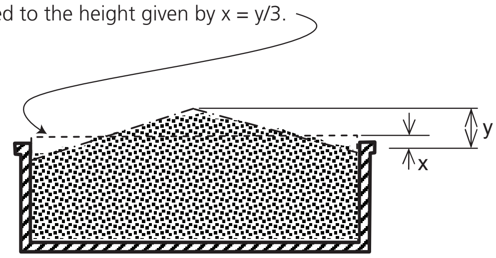


Figure A1.1 Method of estimating the average height of waste heaped up in an open truck or trailer body.

the height of the highest point above the lowest point. [Figure A1.1]).

n) If the body is open, note whether the load is covered with a tarpaulin or net, note how long it takes to cover the load and any risks that the loaders take to spread and fix the cover. As the vehicle moves to the landfill or transfer area, note if any waste is blown out of the truck or trailer.
o) Note the distance travelled to the disposal site or transfer station (odometer reading) and the time of arrival at the discharge point. (If the truck stops at a dealer in recycled waste, note the types, amounts and value of materials recovered and the time taken).
p) Estimate once more the volume of wastes in the truck body and assess how much the volume has reduced and the density has increased during travel.
q) If there is a weighbridge at the disposal site, note the weight of the load. If there is no weighbridge at the disposal site there may be an alternative commercial weighbridge in the locality that can be used to weigh a number of typical loads as a separate study. Weigh loads from different income zones and estimate the volume of each load.
r) Note the time spent at the disposal site or transfer station and the reasons for any delays. Record any observations about any operational problems or risks of injury relating to the unloading operation (for example, whether the vehicle suffers from serious wheelspin when driving on the waste).
s) Note the time and the distance back to the collection area or the vehicle depot.
t) At the end of the day's work refill the truck fuel tank to the very top and note how much fuel has been used, together with the odometer reading.

These observations may be repeated for the same route and vehicle to check that the first day was not abnormal. It is to be expected that the first day after the weekend (if the collection service is not provided seven days a week) will be different from the other working days because there is extra waste to collect.

It is useful to check the observations against any other operational records that are available, such as landfill gatehouse or weighbridge records, or times when vehicles report back to the depot at the end of a shift. By comparing the data recorded from observation with the daily records, it is possible to conclude whether the work that was observed was done in the normal way, and to get an appreciation of the variations that occur from day to day.

A1.3 OTHER TYPES OF OPERATIONAL DATA

A1.3.1 Information about the location

Note the collection area to be studied and estimate the proportions of low, middle and high-income inhabitants. If it is possible to determine the number of households served by the collection route that was studied, this can be used to calculate an approximate generation rate.

It is important to know distances to the disposal or transfer site from the nearest and furthest collection areas, because travel times can have a significant impact on vehicle productivity.

A1.3.2 Information related to particular vehicles

The records at the vehicle depot should be checked to obtain information on the vehicle that was observed, including its age, its expected economic life and the amount spent on repairs and maintenance for this truck during the previous three years. There may also be other useful information such as its size and payload.

A1.3.3 Costs

The best criterion for comparing different systems or evaluating improvements to an existing system is to calculate the unit cost – the cost of collecting one ton or one cubic metre of waste. Two examples of such cost calculations are given in Annex A3. The main costs are listed below:

- The wages paid to loaders and drivers are not the only manpower costs. To these should be added other employment costs, such as any additional allowances and benefits, the costs of replacements during sick leave and paid leave, any social insurance costs, and overheads to cover the supervision and administration associated with each employee.
- Vehicle operating costs include the cost of fuel and maintenance costs.
- The cost of owning the vehicle and other equipment requires information about the initial cost of the vehicle and associated equipment (such as containers), the number of years that they are expected to be in economical use, the allowance for extra (or standby) vehicles so that the collection service can continue when the vehicle is not operational because of maintenance and repairs. It may also be necessary to know the applicable interest rate or opportunity cost of capital (Section 10.3.2).

A1.4 APPLICATIONS OF OPERATIONAL DATA

Work study and other operational data can be used to calculate many useful results which can be used for monitoring, assessing and improving existing systems, and for comparing the benefits of new systems. Some examples are listed below:

- Average speeds are useful when considering whether to collect during the day or at night and when estimating the impact of siting a new landfill at a greater distance from the sources of waste.
- Fuel consumption data can be used to check if fuel is being stolen.
- The most economical sizes and types of truck and the optimum crew sizes can be determined by comparing unit costs.
- The actual waste loads can be compared with the rated load capacity of the vehicle (the manufacturer's specified *gross vehicle weight* [GVW] from which is subtracted the empty *tare* weight including fuel and crew).
- Work study data and unit costs can be used to show the impact of management techniques, including bonus and other incentive systems, improved route planning and preventive maintenance.
- Unit costs can also be used to compare collection systems, including the type of container used, the point and frequency of collection, and the effect of double shift working in place of single shifts, and the use of transfer stations.

PREVENTIVE MAINTENANCE OF COLLECTION EQUIPMENT

A2

A2.1 KEY POINTS

The preventive maintenance programme described in this Annex was set up for a large workshop maintaining a wide variety of different types of equipment with a total of more than 100 vehicles.

Each person involved in a preventive maintenance programme has defined tasks which form part of the overall monitoring system. Each of the functions described is essential to the efficient and reliable operation of a municipal workshop. This programme can be adapted for use by smaller workshops by combining two or more of the functions into a single check sheet, making them the responsibility of one person. The various check and servicing sheets included in this Annex can be used as a checklist for setting up a system that is appropriate to any particular situation, ensuring that no checks are omitted. Data derived from these checks should be made available to the municipal or other authorities concerned so that they can make informed decisions as to the operating and financial budgets required for their particular situation and when to purchase new equipment.

It cannot be stressed enough how important a proper preventive maintenance programme is to the efficient operation of even one vehicle, and how it can reduce both operating costs and financial costs by minimising vehicle *out-of-service* times (downtimes) and the maximising of the vehicle life. An important part of a preventive maintenance programme is to anticipate faults and prevent a minor problem (such as a loose bolt, for example) from developing into a serious failure which may require costly repairs or spare parts. A problem such as an oil leak or a leaking air intake hose, which in itself is a very minor problem, may result in a complete engine, transmission or hydraulic failure if it is not detected in time. The system provides prior warning of any requirements for spare parts so that they can be procured before they are actually needed.

Each person in the maintenance programme is given a defined work schedule and if he does not carry out his scheduled tasks correctly this will be discovered and highlighted by the next more senior person. As a result it is possible to hold an individual mechanic accountable for any vehicle breakdown or other malfunction caused by a lack of diligence on his part. However if each person carries out his duties as set out in his particular work sheet he cannot be blamed for any vehicle malfunction and excessive vehicle downtimes.

The system includes an out-of-service cost so that the cost of having vehicles lying idle while awaiting servicing or spare parts can be calculated and the blame apportioned to whoever is responsible, from the driver or the mechanics, to the stores manager or workshop manager – even right up to the financial controller and the elected representatives who have responsibility for approving budgetary allocations.

In order to ensure maximum efficiency and the longest possible working life, manufacturers of vehicles and items of powered plant and equipment provide recommended preventive maintenance schedules for their products. Any organisation that operates a fleet of vehicles and other equipment should adapt these various individual schedules to a common format so that a planned preventive maintenance programme can be drawn up to spread the maintenance workload uniformly throughout the year. Therefore, though some manufacturers may recommend that particular maintenance tasks should be carried out after specified distances have been travelled or a certain number of operational hours, a new schedule should be prepared that lists these tasks as regular weekly or monthly operations, based on experience and judgement regarding the distances that each vehicle covers in a week or the number of hours that it is used in a week. The conditions under which the equipment operates, including the amount of dust in its working environment, the ambient temperature and the steepness of hills, may also have an impact on the optimal frequency of checks and replacements.

The following sections present the documents and check sheets that together constitute a planned preventive maintenance system. The forms are included in Section A2.16 at the end of this Annex and also on the CD.

A2.2 VEHICLE FOLDER

To enable the planned preventive maintenance programme to be carried out in an efficient and formalised manner, each vehicle or other item of equipment has its own *vehicle folder* which includes a list of all checks to be carried out on a daily, weekly or monthly basis, and records the vehicle's utilisation and performance. This vehicle folder should contain the following:

- equipment master card (form MT11)
- technical inspection sheet
- preventive maintenance schedules (form MT6)
- monthly performance return (form MT5)
- mechanics job cards (form MT2)
- drivers daily sheet (form MT1)

A2.3 DRIVER'S DAILY SHEET (FORM MT1)

This is given to the driver by the dispatcher or supervisor at the start of each shift and, if appropriate, includes a route sheet detailing the route to be covered that day. The driver's working hours should require him to arrive at the vehicle depot 15 minutes before the working shift starts to allow time for the required checks, which are as follows:

A2.3.1 Pre start check

At the start of each shift, simple but defined checks should be carried out by the driver or operator of the equipment and checked ✓ on this sheet. There are 14 simple checks on this sheet.

1	fuel	8	lights
2	oil	9	mirrors
3	water	10	spare wheel
4	tyres	11	wheel brace and jack
5	wheel nuts	12	body fittings / locks
6	oil leaks	13	tachograph* (if fitted)
7	hydraulic fluid leaks	14	odometer (distance gauge) on speedometer

** A tachograph records the operational experience of a vehicle – the times when the vehicle was operational and the speeds it was driven at.*

A second section on the sheet provides information on the work performed if different from the standard route card. A third section details fuel and oil issued and a final section provides information relating to breakdowns, accidents or mechanical problems encountered during that shift.

A2.3.2 Completion check

At the end of the shift the driver or his assistant should clean the truck (or other equipment), refuel it and repeat the pre-start checks to confirm that is in good condition and fit for operation in the next shift.

The dispatcher or supervisor signs the vehicle back in at the end of the shift. If any particular problems are encountered they should be brought to the attention of the workshop supervisor who will sign the form as "fit for service" or "requiring attention". In the latter case he will make out a job sheet according to the problem reported.

The driver's daily work sheet is then placed in the vehicle folder of the particular vehicle or equipment.

A2.3.3 General comments

Each shift requires a separate driver's sheet. The pre-start check on this sheet is a confirmation of the job completion checks from the previous shift but puts the responsibility on each driver or operator to confirm the findings of the previous driver or operator. In this way each driver or operator is accountable. If only one shift is worked and the same driver is allocated to the vehicle for each shift, the completion check can be omitted.

Only minor servicing[46] is carried out by the driver, such as adding fuel, pumping tyres, etc. If more serious servicing is required the vehicle will be referred to the workshop manager for attention.

The Drivers Daily Sheet can be analysed by the office clerk each day or each week to show

- hours worked and distance travelled
- crew size and names (to be used for calculating wages)
- fuel and oil consumption
- work carried out (for example: number of loads collected)
- problems encountered and service repairs carried out by the driver (such as wheel changes following a puncture) and the delay time incurred.
- any damage or accidents during that shift.

A2.4 JOB CARD (FORM MT2)

A job card is issued by the workshop supervisor for a mechanic to carry out the repairs or servicing work specified. The mechanic notes his time on and off the job to allow the total hours for the job to be calculated by the office clerk and entered into the monthly servicing sheet summary (form MT3). A second section on the job card notes any spare parts or materials used on that job. This job card is signed by the mechanic and counter-signed by the workshop supervisor to confirm that the job has been satisfactorily completed.

46. For definitions of the words "servicing" and "service" see the word list in Annex A7.

A2.5 EMERGENCY REPAIR PROCEDURE

A properly implemented preventive maintenance programme greatly reduces vehicle downtimes, partly because most spare parts are procured in time for them to be fitted during the next or a subsequent servicing check without any additional vehicle downtime. However, unforeseen breakdowns and accidents will still occur and provision must be made for such breakdowns to be treated as emergencies so that the vehicle is back in service in the shortest possible time.

It must be appreciated that excessive downtime results in the municipality tying up extra capital resources by purchasing the additional stand-by vehicles that are required to maintain the service while any regular vehicles are awaiting repair. A target should be set of a maximum of 10% of vehicles being out of commission at any time for maintenance or emergency repairs.

The following procedures should apply to any breakdowns:

- Immediate notification should be given to the workshop manager who must personally examine the vehicle and decide what spare parts and manpower resources are required.
- An *emergency parts request* should be made to the stores manager who will confirm whether the parts are in stock, in which case the emergency repair can be performed immediately. If the parts are not available, a supplier must be located and the stores manager must advise the workshop manager as to the likely delay in obtaining the parts so that the routine servicing work can be programmed to allow for this repair.
- Emergency parts requisition forms should be used. These should be in the same format as the regular monthly requisition form but should be brightly coloured to indicate that they have a high degree of urgency.
- If a delay of more than two days is expected, the workshop manager must notify the division head of the likely delay and the reason for the delay.

A2.6 MONTHLY SERVICING SHEET SUMMARY (FORM MT3)

This provides a summary of all the work carried out on that vehicle, or other item of equipment, during that month and includes the information that enables the following data to be extracted by the maintenance clerk:

- maintenance labour time and cost
- parts and material costs
- out-of-service time.

A2.7 VEHICLE SERVICE AND REPAIR SCHEDULE (WALL CHART MT4)

The dates on which servicing and maintenance work is to be performed should be shown on a wall chart in the workshop manager's office and each item should be ticked and dated when the work is completed. This will enable the workshop manager to schedule routine servicing so that each vehicle or other item is maintained on a planned basis with the minimum of delays as well as providing a constantly up-dated confirmation that the servicing has been carried out. It provides advance warning to the stores manager to make available routine spare parts (filters, etc).

A simple tag system can be maintained with a peg board calendar. The peg board is made from hardboard which has holes at a spacing of 20 mm. In the horizontal direction the board should have 52 holes, each hole for one week of the year. It should have sufficient rows so that each vehicle (or other item to be maintained) has its own row. This calendar can be used year after year provided that the information about the vehicles is updated. The workshop manager has a *tag* for each vehicle or other item with its description clearly shown. These tags can be made from golf tees with a label glued to the head showing the vehicle number. (These tags can easily be inserted into the holes in the hardboard calendar, and later removed.) Whenever a vehicle or other item comes in for servicing or repairs, the tag for that particular item is immediately inserted into the board in the workshop manager's office to show the week during which it comes into the workshop. The tag is only removed when that item is returned to service.

This system enables the workshop manager and other senior staff members to see at a glance which items have been out of service for more than one week and for how long they have been out of service. He can then chase up any items which have been in the workshop for a long time and take action accordingly.

A2.8 MONTHLY PERFORMANCE RETURN (FORM MT5)

At the start of each month the workshop clerk should prepare a sheet for each vehicle or item of equipment, showing the previous month's performance and operating cost. It includes for comments by the cleansing manager and the workshop manager on any abnormalities in the vehicle's performance.

A regular analysis of these returns will be used for determining the downtime for each vehicle and the reasons for the downtime in each case to assist with any decisions concerning the economic life of the vehicles (that is, when they should be replaced). This information may also be useful when selecting types and makes of replacement vehicles.

A2.9 PREVENTIVE MAINTENANCE SCHEDULES (FORMS MT6 & 7)

Routine maintenance sheets for each type of vehicle (or item of equipment) should be based on the manufacturer's recommendations and show the servicing and maintenance programme to be carried out on a routine basis. This will include separate sheets for forms MT6 and MT7.

A2.9.1 Weekly preventive maintenance sheet. (form MT6)

This sheet shows the servicing to be carried out on a weekly basis by a junior mechanic and lists each item to be checked. On completion, each item should be initialled by the mechanic. The sheet includes details of all parts and materials used and the amount of time spent to carry out the servicing. The sheet should be signed by the mechanic to confirm that all checks have been carried out and countersigned by the workshop supervisor to confirm that the work has been completed and the vehicle is fit for service.

This sheet is also used to record observations regarding any parts which are showing signs of wear and for which replacement parts will be required for the next or subsequent scheduled maintenance session. An estimate of the remaining life before replacement is required. Any parts noted as being required in the near future should be listed and the list passed to the stores manager for immediate attention. In this way there should be a constantly updated record of the parts used as well as the parts which will be required in the near future so that stocks can be replenished promptly to maintain an adequate parts inventory at all times.

This weekly servicing should take no more than two hours. Consequently, by adjusting the timing of the mechanics' shifts it should be possible to do these checks after the daily collection or other duties have been completed, to avoid any disruption to the normal working.

A2.9.2 Monthly preventive maintenance sheet (form MT7)

This sheet includes all the items in the weekly preventive maintenance sheet and also includes other checks and inspections and monthly servicing requirements as specified by the manufacturers. It includes a road test by the mechanic. Again, advance notice should be given to the stores manager of any parts required for the next scheduled maintenance session so that they can be procured and available when needed.

This monthly servicing requires the vehicle to be taken out of service for a shift, unless it can be done at weekends.

2.10 SIX-MONTHLY INSPECTION (FORM MT8)

Every six months, inspections should be carried out by the workshop manager to ensure that all vehicles and equipment are maintained in good condition and that all maintenance and servicing have been properly carried out. Each year, before the preparation of the annual budgets, one of these inspections should include an *annual equipment audit* to determine the remaining economic life of each vehicle or other item of equipment and to provide estimates for:

- the cost of keeping that item operational for the next twelve months;
- the value of that item if it is sold on the open market (residual value);
- the cost of a new vehicle of equivalent type and size, to replace the old one.

This annual equipment audit will enable informed recommendations to be made for the replacement of obsolete vehicles or equipment, and enable budgets to be prepared for the following year, to include maintenance and operating costs and allocations for purchasing replacement vehicles.

A2.11 SPARE PARTS PROCUREMENT FORM (FORM MT9)

A spare parts procurement form (MT9) lists the parts required from outside suppliers and is used by the stores manager and signed by the department head. Parts should normally be procured on a monthly basis to top up spare parts stocks in the stores. However, whenever parts which are not available from stores are required, they will be procured according to an emergency procedure.

A chart in the workshop manager's office should list the parts that have been requested at any time and the anticipated delivery dates. This can be done using a peg board similar to that described in Section A3.7.

A2.12 STORES STOCK CARD (FORM MT10)

Spare parts stock cards for each part record the purchase and issuing of all spare parts and include *minimum stock levels* to be maintained at all times together with a *reorder stock quantity* which will be set for each regular replacement part (filters, tyres, etc) according to the annual consumption of that part. As soon as the minimum stock level is reached more of these parts should be ordered (according to the number found in the reorder stock quantity) to ensure that the stock level is maintained and that there are always parts in stock to minimise downtimes.

A2.13 VEHICLE MASTER CARD (FORM MT11)

A master card for each vehicle or other item of motorised equipment records details of the vehicle relevant to the preventive maintenance programme. It includes:

- Make and model number
- Year of manufacture
- Serial numbers of engine, chassis, etc
- Paint specification*
- Oil specifications and capacities
- Hydraulic fluid type and capacity
- Tyre size
- Hydraulic hose* and seal specifications
- Brake and clutch fluid specifications

* *Not shown on the form MT11 in Section A2.16, but could be added.*

There are many spare parts (including bearings, clutches, brake linings, hydraulic seals, hoses, batteries, electrical items, windshields, and injectors) which can be purchased by their generic description rather than according to the manufacturer's spare parts number, at greatly reduced prices. If they are regarded as acceptable substitutes, these alternatives should be noted with a cross reference to the manufacturer's part number and a list of approved suppliers included. A qualified engineer is required to check each supplier's specification for quality when drawing up this list. If breakdowns occur because poor quality substitute parts have been fitted, information on the parts and sources of supply which were used should be added to the Vehicle Master Card for future reference and an alternative supplier sought and noted on the parts procurement form.

A2.14 RECURRING PROBLEMS

Regular checks of the servicing sheets should be carried out to identify any recurring problems for each type of vehicle and equipment. If problems are found to be recurring on any item of equipment, the manufacturer should be informed and asked for recommendations on ways of eliminating or reducing the problem.

A2.15 COST OF "OUT-OF-SERVICE" VEHICLES

It is common to find that delays in procurement of spare parts or servicing add greatly to the costs of any vehicle or equipment operation. Additional stand-by vehicles are required to compensate for vehicles which are out of service and breakdowns due to inadequate servicing and delays in obtaining essential parts can add greatly to the downtimes and consequent additional costs.

These downtimes may be caused by the inadequate performance by any of the people concerned in the operation, maintenance and financing of the vehicles.

- Poor driving or inadequate driver's checks may result in breakdowns.
- The use of excessively worn tyres can result in delays due to punctures.
- Inadequate servicing by a mechanic may result in a shortened life expectancy.
- A shortage of servicing staff may result in delays in repairing vehicles.

- Inadequate identification of minor problems (such as a loose bolt) may result in more costly breakdowns and excessive downtimes.
- Inadequate identification of worn parts may result in the stores not being informed in advance of the need to obtain these parts, and consequent delays.
- Delays by the stores manager in initiating the purchase of the parts may cause unnecessary downtime.
- Inadequate financial control may result in short-term finance for parts being withheld without an understanding of how this will affect future costs.
- Inadequate budgeting may mean that funds are not available for repairs or servicing and that vehicles may be kept operating after the end of their economic lives because of a lack of funds for replacing them.

These examples show that the cause of any excessive downtime may be the driver, the mechanic, the workshop manager, the stores manager, the financial controller or others.

An important part of any preventive maintenance programme is to highlight the reasons for delays and to estimate the costs of the delays in order to ensure that they are minimised in the future.

The *out-of-service cost* for a truck is based on its capital cost divided by its economic working life in days, with the possible addition of a sum to cover the interest on the capital involved. It can be used to compare the long-term gains from improved servicing and parts procurement against the short-term savings from reduced maintenance inputs. It can also be used as a benchmark of the performance of a workshop.

Equation A2.1 Example

A truck costing $80,000 has an eight year economic life and works for 300 days per year. The interest rate is 12%. It can be seen that the daily value of the truck is:

$$\frac{80{,}000}{8 \times 300} + \frac{80{,}000 \times 12/100}{300} = \$\ 65.33 \text{ per day*}$$

* An alternative method of calculating the daily cost can use the method shown in Section A3.9.5.

When a vehicle is out of service for more than (say) two days, the cause of the delay should be assessed by referring to the preventive maintenance records so that the cost can then be nominally allocated to the person concerned, and an explanation can be prepared to show how this cost was calculated and why it was allocated to the particular individual. Each person can then see how much his actions, or delays or lack of action over the past year have cost the municipality. This provides a good basis for asking that person to improve his/her way of working.

If, for example, the vehicle described above was kept in the workshop for three weeks (18 working days) because money was not made available for the purchase of parts costing $ 200, it can be seen that the net cost to the municipality (or other operator) of the delay in providing this $200 was:

Equation A2.2

$$18 \times 65.33 = \$\ 1{,}170$$

The sum of $200 is not deducted from this figure because this amount is still required to buy the spare parts needed to return the vehicle to service, but the comparison between $1,170 and $200 emphasises the significance of the delay, and suggests that it could often be worthwhile to find ways of accelerating the delivery of spare parts (such as sending a staff member to another city [if the part cannot be found locally] to buy the part, or using courier service or air freight).

This approach could motivate financial controllers to reassess their allocation of funds for parts procurement.

Each month the downtimes of the vehicles awaiting service should be analysed from the vehicle Monthly Performance Returns and a *monthly downtime cost* computed and presented to the divisional head with an assessment of the reasons for these delays. This calculation can be a very powerful tool for the divisional head when applying for future budgets and when assessing future vehicle requirements.

It is difficult to stress sufficiently how important this preventive maintenance programme is to the reliable operation, long life and safety of the equipment. The discipline required to maintain this preventive maintenance programme is an essential part of any vehicle, plant or equipment operation. Although it may at first sound onerous due to the paperwork involved, once the system is set up it is very simple to maintain and, in addition to ensuring that proper preventive maintenance is carried out to ensure maximum vehicle life, it will provide the information for an accurate costing and budgeting system in the future.

A2.16 EXAMPLES OF FORMS

The following pages show examples of the forms that have been referred to.

These forms should be adapted to local conditions. It may be necessary to change the language that they are written in. Even if English is used, there will need to be changes in the words used. There are many examples of different words being used in English, among them:

- a "fender" in the USA is a "wing" in Britain;
- a "hood" in the USA may be called a "bonnet" in England;.
- a "skip truck" in England is a "dumper placer" in India and a "load lugger" in the USA.

The forms will also need to be adapted and extended according to the types of vehicles and other equipment that are in use and need to be maintained. Even after the forms have been modified, it may be necessary to change some parts of them after they have been used for a few months if it becomes clear that they are not being used correctly because of misunderstandings. These forms can also be found on the CD so that they can be modified and printed out, ready for use.

DRIVER'S DAILY SHEET FORM MT1

Location ……………………………………….. Vehicle No. ………………………………

Driver's name ………………………………… Date ………………………………………

Vehicle duty ………………………………….. No. in crew (excluding driver) ....

Dispatcher's name ……………………………

CHECKS: Driver's complaints

1 Fuel / oil / water ☐
2 Tyres / wheel nuts tight ☐
3 Steering / brakes ☐
4 Mirrors / indicators / horn ☐
5 Lights / reflectors ☐
6 Leak in oil / water / air system ☐
7 Body fittings ☐
8 Hydraulic operation / reservoir ☐
9 Electrical couplings ☐
10 Spare wheel / jack / brace ☐
11 Tachograph (if fitted) ☐
12 Routing card OK ☐

13 Odometer reading start …………….km finish ………………km total …………………km

14 Time start ………………… finish …………………. total ……………………

JOURNEY / WORK or number of loads ………………….. Total …………………….

Req. No.	From	To	Work	Volume or load	Remarks

FUEL DRAWN

Issuer	Coupon No.	Litres	Station	Cost	Total

REMARKS

……………………………………… ………………………………………
Driver's signature Dispatcher's signature

This form is to be completed and given to the supervisor at the end of the shift

JOB CARD FORM MT2

Location ………………………………………..   Equipment No. …………………………

Odometer reading ……………….………km   Equipment type / model…………………

Date in …………………out………………...   Mechanic's name ………………………..

1. Repairs / service (Description of work)

		Time		
1		On	Off	Total hours
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
Total	**Hours this sheet**			

2. Spares / materials utilised

Item	Description (incl. tyres and oil)	Part No.	Quantity	Unit cost	Total cost
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
				Total cost	

Signed ………………………………………………………………………………

Mechanic   Supervisor

MONTHLY SERVICING SHEET SUMMARY FORM MT3

Location ……………………………………….. Vehicle No. …………………………

Month ……………….………………………….

Date	In	Servicing/repair	Out	Labour hours	Rate	Labour cost	Direct materials	Cost	Total cost
Total		Downtime estimate ……..hrs							

Wall chart in the Workshop Manager's office

VEHICLE MAINTENANCE AND REPAIR SCHEDULE FORM MT4

Year ………………………………

Location ………………………..

Week No. / Vehicle No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	45	46	47	48	49	50	51	52

Month …………………

TOTALS THIS MONTH

Distance travelled …………………… km

Time worked …………………………. hours

Time idle ……………………………… hours

Time for repair ……………………….. hours

Number of loads ……………............

Estimated volume of waste …………. m^3

Estimated tonnage of waste ………… tons

Fuel utilised ………………………….. litres

Oil utilised ……………………………. litres

Fuel cost ………………………………...

Cost of repair materials ………………..

Cost of maintenance labour ……………

Total service cost ……………………….

Crew labour cost ………………………..

Capital cost ………………………………

Overhead cost …………………………..

Insurance cost …………………………..

Total cost this month ……………………

RATIOS

Cost per ton ……………………………...

Cost per cubic metre……………………..

Cost per km……………………………….

Cost per litre………………………………

Average volume (m^3) collected per litre ………….

Average volume (m^3) per month…………………….

REMARKS

………………………………………

Supervisor

WEEKLY PREVENTIVE MAINTENANCE CHECK SCHEDULE FORM MT6

Location ……………………… Date ………………………….

Vehicle no…………………….. Odometer reading ………m Name …………………………..

1	Drain fuel filter	☐	Remarks
2	Drain air brake cylinders	☐	
3	Clean first stage air filter	☐	Time: on …………….. off………………
4	Check engine oil level	☐	Hours
5	Check gear box oil	☐	
6	Check steering	☐	
7	Check brake and clutch fluid levels	☐	
8	Check battery electrolyte & terminals	☐	
9	Check radiator & oil cooler for debris	☐	
10	Check fan belt tension & adjust	☐	
11	Check clutch & brake pedal travel	☐	
12	Check steering linkage and play	☐	
13	Grease all nipples	☐	
14	Check wheel nuts	☐	
15	Check tyre pressures & damage (incl. spare)	☐	
16	Check indicators, lights and horn	☐	
17	Check for oil, air &r fuel leaks	☐	
18	Check body fittings & locks	☐	
19	Check hydraulic reservoir	☐	
20	Check tachograph for operation	☐	
21	Check radiator fluid	☐	
22	Check tools and spare wheel	☐	
23	Test vehicle on road: normal	☐	
24	Check all functions are stable (temperature & oil pressure)	☐	
25	Check loose bolts	☐	
26	Check drive shaft "U" joints	☐	
27	Check springs not broken	☐	
28	Check shock absorber bushes	☐	
29	Lubricate locks and hinges	☐	
30	List parts required at next service	☐	Make list of back of this sheet for stores – estimate when needed.
31	Any accident damage?	☐	
32	Vehicle fit for duty?	☐	OK
33	Vehicle not fit for duty?	☐	Action required:

signed: ……………………………………………………………………………………

Mechanic Date Supervisor Date

MONTHLY PREVENTIVE MAINTENANCE CHECK SCHEDULE FORM MT7

Location ……………………… Date ………………………….

Vehicle no…………………….. Odometer reading ………m Name …………………………..

1	Drain & replace fuel filter	☐	Remarks
2	Drain air brake cylinders	☐	
3	Replace air filter	☐	Time: on …………….. off……………….
4	Replace engine oil and filter	☐	
5	Top up gear box & differential oil	☐	
6	Top up steering box oil	☐	
7	Check steering movements	☐	
8	Check brake & clutch fluid levels	☐	
9	Check battery & clean terminals	☐	
10	Blow through radiator & oil cooler debris	☐	
11	Adjust fan belt tension	☐	
12	Adjust clutch & brake pedal travel	☐	
13	Grease all nipples	☐	
14	Tighten wheel nuts	☐	
15	Blow out brake drums	☐	
16	Check tyre pressures & tyre damage	☐	
17	Check indicators, lights and horn	☐	
18	Check alternator is charging correctly	☐	
19	Check for oil, air & fuel leaks	☐	
20	Check & lubricate body fittings & locks	☐	
21	Top up hydraulic oil	☐	
22	Check tachograph operation	☐	
23	Top up radiator fluid	☐	
24	Check tools complete	☐	
25	Check loose bolts	☐	
26	Check exhaust leaks	☐	
27	Check drive shaft & bolts	☐	
28	Inspect leaf springs	☐	
29	Inspect suspension bushes	☐	
30	Test vehicle on road: normal	☐	
31	Check brakes pull straight & evenly	☐	
32	Check all functions are stable	☐	
33	List parts required at next service	☐	
34	Fit parts required at previous check		Action required:
35	Accident damage noted?		
36	Vehicle fit for duty?		

signed: ……………………………………………………………………………………

Mechanic Date Supervisor Date

SIX MONTHLY TECHNICAL INSPECTION FORM MT8 page 1

Vehicle No.	Manufacturer:	Model:
Year	Chassis No	Motor No.
Location	Date of issue	km reading

Item	Diagnosis	Satis-factory	Repair	Replace	Man hours labour	Cost of parts
Frame & brackets						
Bumpers						
Hood & fenders						
Body						
Canvas						
Paint						
Doors						
Windshield & windows						
Wiper motor & blades						
Horn & mirrors						
Instrument panel						
Seats & upholstery						
Floor & trim						
Engine						
Cylinder head & block						
Valves & piston rings (compression)						
Manifolds						
Oil pan						
Oil pump & lines						
Oil filter & elements						
Radiator						
Thermostat & hoses						
Water pump & pan						
Drive belts						
Air compressor						
Exhaust emissions						
Sub totals						

SIX MONTHLY TECHNICAL INSPECTION FORM MT8 page 2

Item 1	Diagnosis 2	Satisfactory 3	Repair 4	Replace 5	Man-hours labour 6	Cost of parts 7
Master cylinder						
Air Hydraulic. cylinder						
Wheel cylinder						
Brake shoes						
Brake drums						
Brake lines						
Handbrake						
Steering						
Springs						
Shackles						
Shock absorbers						
Wheels						
Tires and tubes						
SUB - TOTALS						

WORK REQUIRED	
DESCRIPTION	COST
Total	

ELEMENTS FOR EVALUATION OF VEHICLE

8 ORIGINAL COST OF VEHICLE $

9 CURRENT DEPRECIATED VALUE $

10 TOTAL ESTIMATE OF REPAIR COSTS:
LABOUR ……Man-hours @ …… $
SPARE PARTS $
TOTAL COST $

11 COST of MAINTENANCE LAST 6 MONTHS
LABOUR $
SPARE PARTS $
TOTAL $

12 AVERAGE CONSUMPTION LAST 6 MNTHS
FUEL $
OIL $

13 COMMENTS & RECOMMENDATIONS

DATE OF INSPECTION	FIELD	SIGNATURE OF INSPECTOR

SPARE PARTS PROCUREMENT FORM FORM MT9

ORDER No. ………………………….

From (Purchaser): …………………………………………………..Telephone No. ………………………..

Address ………………………………………………………………………………………………..

To (Supplier): ………………………………………………………Telephone No. ………………………

Address ………………………………………………………………………………………………..

Account No. ……………………………….. Equipment type ………………………………………………

Item	Description	Part No.	Cost	Number required	Total cost
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					
				Total value of this order	

Delivery required:

Signed ....

Stores Manager　　Date　　Dept. Manager　　Date

Delivery received: Date .... By:...............................

Delivery completed: Date .... By:...............................

Payment completed: Date .... By:...............................

Parts on inventory list: Date .... By:...............................

(3 copy NCR form)

STORES STOCK CARD FORM MT10

Model No. ……………………………. Equipment type …………………………….

Supplier ………………………………………………………………………………………………………..

Part description ……………………………………………………………………………………………..

Part number ……………………………………

Reorder level ………………………………….. Reorder quantity ……………………………

Item cost ……………………………………….. Delivery time

	Date	Number removed	Number purchased	Balance in stock	Remarks

VEHICLE MASTER CARD FORM FORM MT11 page 1

1	Vehicle registration number		
2	Make of vehicle		
3	Type of vehicle		
4	Year of manufacture		
5	Use or department		
6	Weight of empty vehicle	kg	
7	Maximum operating weight (GVW)	kg	
8	Maximum front axle load	kg	
9	Maximum rear axle load	kg	
10	Length, width, height	cm	
11	Wheelbase	cm	
12	Chassis number		
13	Engine number		
14	Type of engine	Diesel / Gasoline	
15	Turbo installed	Yes / No	
16	Horsepower at ………rpm	hp	
17	Flywheel power at ………rpm	hp	
18	Horsepower at PTO at ………rpm	hp	
19	Compression ratio		
20	Number of cylinders		
21	Engine displacement	cm^3	
22	Spark plug spec. / contact ref (gasoline only)		
		Type	**Serial No.**
23	Transmission		
24	Gearbox		
25	Front differential		
26	Rear differential		
27	Steering		
28	Clutch		
29	Torque converter		
30	Air conditioner pump		
31	Turbo		
		Capacity (litres)	**Oil type**
32	Fuel tank		
33	Cooling system		
34	Crankcase		
35	Transmission		
36	Front differential		
37	Rear differential		
38	Hydraulic tank		

VEHICLE MASTER CARD FORM FORM MT11 page 2

Wheels		**Front**	**Rear**
39	Type of brakes	Disk / Drum	Disk / Drum
40	Size of rims		
41	Size of tyres		
42	Specification of tyres		
43	Tyre pressures		

Superstructure or body					
44	Type of superstructure				
45	Make of superstructure				
46	Size of tipper container	L cm	W cm	H cm	V m^3
47	Lifting capacity of crane	minimum	kg	at	m
48	Lifting capacity of crane	maximum	kg	at	m
49	Lifting capacity (skiplift)		kg		
50	Pulling capacity (roll on/off)		kg		
51	Lifting capacity (excavator)		kg		
52	Lifting capacity (shovel)		kg		

Hydraulic rams		**Number**	**Max operating pressure kg/cm^2**	**Seal code**
53	Tipper rams			
54	Shovel bucket lifting			
55	Shovel bucket positioning			
56	Shovel steering			
57	Excavator main boom			
58	Excavator top boom			
59	Excavator bucket			
60	Excavator sliding			
61	Excavator jacks			
62	Crane main boom			
63	Crane top boom			
64	Crane jacks			
65	Hooklift main rams			
66	Hooklift sliding			
67	Skiplift main rams			
68	Skiplift jacks			
69	Trailer coupling			
70	Trailer tipper			

71	Total value of vehicle	
72	Date of entry into service	
73	Year of replacement	

FINANCIAL COMPARISON OF COLLECTION SYSTEMS

A3

This Annex presents a simplified scenario to show how to compare two very different solid waste collection systems which are being considered for one specific situation. In practice, different systems are usually required for the different commercial and residential areas of a city, and different levels of service would be provided for different income levels. Therefore the area considered in this example is not the whole of the city, but the older and more densely settled districts, commonly known as Old City.

A3.1 THE SCENARIO

Following a study tour of a European country, including a visit to a compactor truck manufacturer (called Pakatruk), the Mayor wants to introduce rear-loading compactor trucks with 80 litre wheeled plastic “tote” bins and a twice per week collection. He has been convinced by the Pakatruk engineer that this is the “modern” method of waste collection. At his invitation, an engineer from Pakatruk spent three weeks in Old City and prepared a proposal, the details of which are provided below. There are two options for financing the new scheme: one is a loan from the Economic Development Administration of the country where the Pakatruk factory is located, and one is from a Development Bank.

The City Engineer has also been on a study tour. He visited China, Vietnam and Egypt and was impressed by some of the waste collection systems that he saw in these countries. When he learned that the Mayor was interested in establishing a new waste collection system, he also prepared a proposal for a collection service that would use small vehicles to collect waste from houses and commercial areas and bring it to transfer stations, from where it would be taken by larger trucks to the disposal site. His proposal includes collection three times a week.

A3.2 SOURCES OF INFORMATION

The information that is needed to calculate the costs of the proposed systems can be divided into several categories:

- General information about Old City. This is information that is readily available from the local library, administration offices, reports and websites.
- Observations. By walking or driving around the city one can learn a lot about factors affecting transport, shops and services, and the habits of the people.
- Proposals – the data and calculations that have been used to estimate the requirements of the proposed system, and the proposals themselves, in terms of service levels, requirements for manpower and machinery, and timing.
- Existing specialised information that may be available from workshop records or the accounts and budgeting department.
- Additional information which is not currently available or must be determined in the field, by measurement and observation, or from experience in similar situations. Some available data may need to be checked because it is out-of-date, because there is no information about how these data were obtained, or because it has a major influence on the result, and so must be known with more accuracy or confidence that other data. The guidelines provided in Annex A1 are relevant here.

It is necessary to emphasise that this example is simplified so that it does not become too long and detailed. Actual cost calculations require more investigations to determine the information that is needed. The purpose of these calculations is not to justify a loan or to set budgets, but to develop an initial comparison of two systems, and for this purpose it is reasonable to make some simplifying assumptions.

A3.3 GENERAL AND BACKGROUND INFORMATION ABOUT OLD CITY

The whole city has a population of 2.43 million, but the population of Old City is 750,000. The average household size is 4.9. Most of the residents in Old City use charcoal and wood for cooking. The unit of currency is the Munni, the symbol for which is ♍.

A3.4 OBSERVATIONS IN OLD CITY

Many of the streets in Old City are narrow and congested, and cannot accept vehicles more than 2 m wide.

Concrete compounds (bunkers) are used for storing the waste in the streets. The waste is loaded into open tipper trucks by raking it into flat baskets and passing them up to a labourer who stands in the truck, and the whole operation is slow and unhygienic. The trucks have a high loading height and a capacity of about 6 m^3. There are signs of rats around the bunkers and blackened walls show that the wastes have been burned in many bunkers. The waste contains ash and considerable amounts of sand, especially where the lanes are not paved. The waste generally contains a large proportion of wet food waste, and most of the bunkers have unpleasant smells.

There is a considerable amount of waste in the open drains, and many residents complain about nuisance from mosquitoes.

Only the main roads are hard surfaced. During the daylight hours the traffic in the city is very congested. Parked cars, and trucks and minibuses stopping at intervals, cause frequent traffic jams.

A3.5 THE PROPOSALS

A3.5.1 The Pakatruk proposal favoured by the Mayor

It is proposed to collect all the waste of Old City. Plastic wheeled bins, having a capacity of 80 litres, will be distributed among the population, so that one bin is shared between four households. The bins will be left on the street and emptied twice a week by compactor trucks with mechanical bin lifts which can tip two bins simultaneously into the loading hopper.

Each truck will work a full 8 hrs per day. (If time is allowed for roll-call and preparations before starting work and for a meal break, it will be necessary to add this on to the 8 hours working time.) The model of truck suggested is a single axle (4 x 2) compactor truck with a GVW of 15,000 kg, and an empty weight of 9,000 kg so that the payload is 6,000 kg. It will work 6 days per week and collect two loads or 12 tons per day, with a crew of four loaders and a driver. It is estimated that the truck can be loaded in 90 minutes, and that the time spent unloading at the landfill is 10 minutes.

A standby allowance of 25% will be allowed to ensure that the service is fully provided when some of the vehicles are in the workshop for maintenance and repairs. (This is equivalent to an anticipated availability of 80%.)

A3.5.2 The small transfer station proposal of the City Engineer

The City Engineer has proposed the introduction of four small "downtown" transfer stations using micro-trucks to collect the wastes from the houses and commercial areas, also working 6 days per week. These trucks will be equipped with loudspeakers that play a recognisable tune so that residents know when to bring their waste out to the micro-trucks, which will stop at regular intervals. Wastes left at the kerbside in containers provided by the householders will also be collected by the crews. The micro-trucks have a capacity of 2 m^3 and will operate within a range of only 3 km from the nearest transfer station. It is estimated that each collection round will take 44 minutes – 12 minutes travelling, 28 minutes loading and 4 minutes unloading. Each micro-truck will be operated by a driver and one labourer; the driver will be expected to help with the loading on occasions. The standby allowance for these vehicles is set at 20%, (lower than for the compactor trucks because the vehicles are much less complex and the spare parts are readily available on the local market). Based on his experience, the City Engineer has based his calculations on 6 hours of productive work per shift, to allow for roll-call, driving to and from the vehicle depot and other delays.

The transfer stations will use the "double pit and hoist" (STS) system (described in Section 8.2.4) with two pits and storage capacity for seven containers of wastes – six plus one on the transfer truck. The transfer containers will have a capacity of 30 m^3 and, with a small amount of self-compaction due to the depth of wastes in the containers, will hold 14,000 kg of wastes. Each container will be filled to its full load capacity using the weigh cells at the bottom of the pits to control the loads and prevent overloading. The 6 x 4 transfer vehicles will have a gross vehicle weight (GVW) of 24,000 kg. Primary collection will take place during the day time and evening and secondary transport from the transfer station to the disposal site will be done at night when traffic speeds are higher and to avoid adding to the traffic congestion. The time needed for loading a container will be 8 minutes and the time on the disposal site 10 minutes. The trucks will operate six nights a week, working 8 hours each night, with a break of 20 minutes. Each truck will normally serve only one transfer station, but when required they can be used to collect containers from other transfer stations. One extra vehicle will be on standby for occasional peak loads. Thus the four transfer stations and the five vehicles (4 + 1 standby) will be able to transport all the waste that is collected. Each transfer vehicle will have a driver plus an assistant, and each transfer station will be manned by two attendants.

A3.6 OTHER SPECIALISED INFORMATION

Depreciation periods for various types of asset have been set as follows:

- Compactor trucks. 5 years *
- Micro trucks 7 years
- Container transport trucks 7 years
- Wheeled bins 4 years
- Transfer containers 5 years **
- Transfer station 20 years ***

** The life of the compaction truck has been reduced from that of an ordinary truck because of the abrasive and acidic nature of the wastes. This is in line with experience in many countries.*
*** If the containers are manufactured from CorTen steel their depreciation period could be increased to 10 years.*
**** There will be a small maintenance cost and reduced life expectancy on the hoists in the transfer station.*

The price paid by the Municipality for diesel fuel is ♍2.57 per litre. Fuel consumption for the large trucks is estimated to be 100 litres per shift and for each micro-truck 20 litres per shift. It is estimated that annual maintenance costs will be about 7.5% of the capital costs of the vehicles. It is estimated that the electric power consumed by one transfer station for lighting and the operation of hoists and other equipment will not be more than ♍ 27,000 per year.

Anticipated purchase prices

Item	Unit price ♍	Comments
80 litre wheeled bin	216	Unit price for orders of over 20,000 units
compactor truck	209,250	
micro-truck	81,000	
30 m³ container	13,500	fabricated locally from mild steel
container truck	243,000	6 x 4, with hydraulic tipping frame
transfer station	432,000	excluding land

Note: The costs for any particular system differ from country to country. However the following costs are indicative of costs at the time of writing in one country where the author was working shortly before compiling this example. The cost of land is not included in the cost of the transfer stations, as the municipality already has suitable sites.

A3.7 INFORMATION FROM INVESTIGATIONS

The waste generation rate in Old City is 0.3 kg/cap/day (based on existing weighbridge data and the population currently served). The average density of waste in the open trucks is 400 kg/m^3.

The average speeds for journeys within Old City are measured to be 15 km/h for large trucks and 20 km/h for small trucks and cars. The average speed for all types of vehicles at night in the urban area is 28 km/h. The wastes are disposed at a new landfill site which is 24 km from the city boundary, and the average travel speeds on the road to the disposal site are 35 km/h during the day and 55 km/h at night. The average one-way travel distance within the urban area for both types of large truck is estimated to be 5 km.

The employment costs for drivers and labourers were calculated to be as follows:

- Drivers: ♍ 9,450 per year
- Labourers: ♍ 6,885 per year

These costs include overheads to pay for supervision and administration, and allowances for leave and social insurance (including redundancy, retirement pensions and sick pay) and also the wages of casual or permanent staff who replace those who are on leave.

The calculation table on the following three pages is taken from a spreadsheet which is included in the files on the accompanying CD. By clicking on any spreadsheet cell which contains a calculated value, it is possible to see how that value was calculated.

There are many advantages in using computer spreadsheets for such calculations. They encourage careful and methodical working. They show how each value has been calculated. If a mistake is discovered in any entry the final result is instantly recalculated. Most importantly, they allow investigation of the impacts of changes in one or more variables. Having said this, the mathematics of the calculations is extremely simple, and such calculations can easily be performed on paper using a simple pocket calculator.

Following the table there is a brief discussion of what can be learned from this exercise and of the limitations of this approach, and some supplementary calculations.

A3.8 CALCULATING THE COSTS OF WASTE COLLECTION SYSTEMS

A3.8.1 General data

Notes:
The unit of currency is the Munni, and it is shown as ♍
The numbers in the first column are the line numbers of the spreadsheet programme
Items marked "d" are data that are provided. Other figures are calculated.
Items marked "s" are calculated results that are used in summing the costs.

10	d	Population served	750,000		
11	d	Household size	4.9	people per household	
12	d	Waste generation rate	0.3	kg/cap/day	
13	d	Bin emptying frequency	2	times a week	
14		Longest interval between collections	4	days, after weekend	
15	d	Working days	6	days per week	
16		Working days per year	312	days per year	
17	d	Working hours per shift	8	hours	
18	d	Waste density in open trucks	400	kg/m^3	or 0.4 kg/litre
19	d	Employment cost for drivers	9,450	♍ per year	
20	d	Employment cost for labourers	6,885	♍ per year	
21	d	Fuel price	2.57	♍ per litre	
22	d	Distance in urban area (compactors)	5	km	
23	d	Speed in urban area (large trucks)	15	km/h	
24	d	Speed in urban area (small trucks)	20	km/h	
25	d	Speed in urban area at night	28	km/h	
26	d	Distance outside urban area	24	km	
27	d	Daytime speed outside city	35	km/h	
28	d	Night-time speed outside city	55	km/h	
29	d	Estimated maintenance cost as %	7.5	% capital cost/year	
30		Depreciation periods			
31	d	Compactor trucks	5	years	
32	d	Micro-trucks	7	years	
33	d	Container transport trucks	7	years	
34	d	Wheeled bins	4	years	
35	d	Transfer containers	5	years	
36	d	Transfer station	20	years	
37					
38		**Calculations**			
39		Number of households served	153,061	[750,000/4.9]	
40		Total weight generated in one day	225,000	kg/day [750,000 x 0.3]	
41		or	225	tons/day	
42		Weight generated by one household			
43		after longest interval (4 days)	5.88	kg	[4 x 4.9 x 0.3]

A3.8.2 Comparing the systems

48			A. Compactor trucks			B. Small transfer station	
49		**Wheeled bins**	**quantity**	**units**		**quantity**	**units**
50	d	Households sharing a bin	4				
51		Weight of waste in bin when collected	23.52	kg			
52		Maximum volume of waste in bin	58.8	litres			
53		therefore 80 litre bins are big enough					
54		Number of bins required	38,265				
55	d	Cost of one bin	216	♍			
56		Total cost of bins	8,265,306	♍			
57							
58		Average weight collected per week	1,575,000	kg		1,575,000	kg
59		Weight collected per working day	262,500	kg		262,500	kg
60		or	262.5	tons		262.5	tons
61							
62		**Trip time – Compactor and micro-truck**					
63	d	Time for loading in one trip	90	minutes	d	28	minutes
64		Travel time in urban area (2 ways)	40	minutes	d	12	minutes
65		Travel time outside urban area (2 ways)	82	minutes			
66	d	Time unloading on landfill	10	minutes	d	4	minutes
67		Therefore total time for one trip	222	minutes		44	minutes
68	d	Time utilisation allowance	95	%	d	75	%
69		Number of trips per shift	2			8	
70	d	Maximum load truck can carry	6	tons	d	2	m³
71					or	800	kg
72		Therefore number of trucks	22			41	
73	d	Standby allowance for trucks	25	%	d	20	%
74		Number of trucks needed	28			50	
75	d	Cost of one truck	209,250	♍	d	81,000	♍
76		Total purchase cost of trucks	5,859,000	♍		4,050,000	♍
77	s	Maintenance cost of trucks	439,425		s	303,750	♍/year
78							
79		**Trip time – Container transport truck**					
80		Time for loading in one trip			d	8	minutes
81		Travel time in urban area (2 ways)				21	minutes
82		Travel time outside urban area (2 ways)				52	minutes
83		Time unloading (on landfill or at STS)			d	10	minutes
84		Therefore total time for one trip				92	minutes
85		Time utilisation allowance			d	95	%
86		Number of trips per shift				5	
87		Maximum load truck can carry			d	14	tons
88		Therefore number of trucks in daily use				4	
89		Standby allowance for trucks				20	%
90		Total number of trucks needed			d	5	
91		Cost of one truck			d	243,000	♍
92		Total purchase cost of trucks				1,215,000	♍
93		Maintenance cost of trucks			s	91,125	♍/year
95		**Small transfer station and containers**					
96		Number of transfer stations			d	4	
97		Cost of one transfer station			d	432,000	♍
98		Cost of one container			d	13,500	♍
99		Number of containers in one STS			d	7	
100		Storage provided by containers				392	tons
101		Total cost of containers				378,000	♍

			A. Compactor trucks			B. Small transfer station	
103		**Wage costs**					
104		Number of drivers	22			45	
105	d	Number of loaders on each collection truck	4		d	1	
106		Number of assistants on each transport truck			d	1	
107		Number of loaders	88			45	
108		Attendants at each transfer station (paid as labourers)			d	2	
109		Total transfer station attendants				8	
110	s	Wage costs	813,780	♍/year	s	790,155	♍/year
111							
112		**Energy**					
113	d	Daily consumption of one collection truck	100	litres/day	d	20	litres/day
114	d	Daily consumption of one container truck			d	100	litres/day
115	s	Cost of fuel for all trucks	1,764,048	♍/year		978,245	♍/year
116		Electricity consumption at one transfer station			d	27,000	♍/year
117		Annual energy costs			s	1,086,245	♍/year
118							
119		**Depreciation**					
120		Transfer station depreciation			s	86,400	♍/year
121	s	Compactor trucks	1,171,800	♍/year			
122	s	Wheeled bins	2,066,327	♍/year			
123		Micro-trucks			s	578,571	♍/year
124		Container transporters			s	173,571	♍/year
125		STS containers			s	75,600	♍/year
126							
127		**Summary of annual costs**					
128		Depreciation of bins and containers	2,066,327	♍/year		75,600	♍/year
129		Depreciation of vehicles	1,171,800	♍/year		752,143	♍/year
130		Depreciation of transfer stations				86,400	♍/year
131		Maintenance of vehicles	439,425	♍/year		394,875	♍/year
132		Wage costs	813,780	♍/year		790,155	♍/year
133		Fuel costs	1,764,048	♍/year		1,086,245	♍/year
134		Total costs	6,255,380	♍/year		3,185,418	♍/year
135							
		Total waste generated per year	82,125	tons/year		82,125	tons/year
138		**Unit cost of waste collection**	**76**	**♍/ton**		**39**	**♍/ton**

A3.9 DISCUSSION OF RESULTS

A3.9.1 The significance of the unit cost

With the data used here, the system using compactor trucks and wheeled bins is twice as expensive as the system based on the small transfer station. It is hoped that the City Engineer is able to use this clear difference to persuade the Mayor to consider this alternative to the system that he has promoted. The cost figures are very persuasive. Perhaps the mayor would agree to convening a workshop at which various experts (including the Pakatruk salesman) would be invited to reconsider the way forward.

It must be emphasised that this calculation is for comparison purposes, not for determining a budget or contract price. The whole calculation is based on one figure – 0.3 kg/cap/day – and an apparently small variation in this figure could have a major influence on the total costs, though the comparative costs would not be affected enough to bring a different conclusion. When deciding on the numbers of containers and vehicles, it must be remembered that the whole calculation is based on this generation rate, so there should be some flexibility to cope with additional quantities of waste, including the effects of seasonal variations, population growth, increases in per capita generation and extending the service to new areas. Sometimes generation rate data are concerned only with domestic waste, so such figures must be increased to include commercial, institutional and other wastes.

It is also important to remember that this analysis is for one particular situation and the data used to describe it. It would be wrong to assume that compactor trucks are always twice as expensive as systems using small transfer stations. For example, if no containers were provided (because the residents were required to pay for them), the cost for the compactor service would drop to ♍ 51 per ton. However, if wheeled bins were not used at all, the collection time would increase and the whole calculation would be changed.

A3.9.2 Looking at other figures

It is useful to look at the summary of the various costs to see which items are the main expenses. For the compactor truck system, the largest item of expenditure is the depreciation on the 80 litre wheeled bins. Depreciation is a difficult issue because many municipal administrations are not accustomed or able to set aside reserves for future capital expenditure. The bins themselves are likely to be the cause of certain problems, as discussed in Section A3.9.4. It is likely that a significant number of additional bins will be needed to replace bins that are damaged and misused, so the expenditure on bins will be even higher.

Fuel costs are the second-largest item in the compactor system, and the largest item for the transfer system, and the likelihood of increases in oil costs must be borne in mind.

Looking at the journey times, it can be seen that the compactor trucks would spend more than half of their working life transporting waste to the landfill and returning to the city. Compactor trucks are designed for collection rather than transport, and are not as efficient as other vehicles when transporting waste over longer distances.

A3.9.3 Reviewing some assumptions

It should be noted that the compactor truck system is based on working 8 hours per day whereas the micro-trucks are working a more realistic 6 hours per day. The compactor trucks need to work a full eight hours in order to collect two loads. The assumption that the compactor truck crews will work eight hours each day may be a problem. Normally the productive working time is less than the full shift, because of the time taken to organise the crews and travel to the collection area at the beginning of each shift, and back to the depot at the end. Actually, it is the drivers who will be obliged to work longer than the shift time, because they will need to do the vehicle checks before leaving the depot and they travel to and from the landfill. The collection crew do not need to travel to the landfill site, though one of the loaders may be required to accompany the driver, perhaps on a rotation basis, to assist in reversing and in operating the truck. The drivers of the container trucks would also be required to work a full shift.

The use of the figure of 7.5% to calculate the maintenance costs of all three types of vehicle may need to be revised. Compactor trucks have many moving parts and hydraulic cylinders, and often have complex control systems, and so they require more maintenance than simple trucks. They are also more subject to corrosion and abrasion. The adequacy of the 25% standby allowance for compactor trucks may not be enough, particularly if many of the spare parts must be ordered from Europe.

It would be possible to reduce vehicle numbers in both systems by working two shifts each day.

A3.9.4 Non-financial issues

The financial analysis that is illustrated in this Annex should be the last stage in a selection process. Before considerable effort is devoted to collecting operational and financial information, and costs are calculated, there should be a review of a wide range of possible collection systems, and systems that are unsuitable should be discarded, so that the comparison of costs is done only for suitable options.

There are several problems with the compactor truck system described here. The loading system is based on the binlift system that tips the bins into the hopper of the truck. This system only works if bins that are designed for this process are used. The use of bins in this situation may face the following problems:

- Since they are shared between households they must be left in the street. Since they are easy to move they may be stolen, taken to serve as goalposts for street football or damaged by passing vehicles.
- Being shared between households, the residents may feel little responsibility for them. They may be taken for other uses, such as storing fuel, bathing babies and brewing beer.
- Since there are significant quantities of ashes in the waste, it is likely that hot ashes will be put into these containers so that they will be damaged or destroyed. Any attempt to burn waste in these bins will destroy them.

Another problem with this system is that compactor trucks are not suitable for high-density wastes and for wastes with significant quantities of abrasive materials and wet biodegradable material, as discussed in Section 7.8.1.

Large, 15 ton GVW compactor trucks are not suited to narrow lanes, in terms of their size and their weight. If they are able to pass though the lanes they will cause serious congestions and traffic jams as they stop to load the waste. They may also damage the road surfaces and pipes beneath them.

The lifetimes of the components of the compactor truck system are shorter than for the transfer system. Since it is unlikely that international financing will be available to replace the bins and compactor trucks, it is better to implement a system that has a longer working life, to give more opportunity for introducing a system of staged annual replacement.

The frequency of collection could be an issue. Residents may object to waste being uncollected in their bins for four days with the compactor system. They may object more strongly to keeping wastes on their premises for three days, in the case of the transfer system because they have been accustomed to taking their wastes to the bunkers at any time.

Considering the transfer system, it would be wise to consider the use of handcarts or pedal tricycles or other simple vehicles as a means of collecting waste from neighbourhoods close to the transfer stations. However, since the Mayor seems concerned that the system appears modern, it is probably wise to propose motor vehicles for primary collection at this stage. The use of smaller container trucks with single rear axles might be considered before the detailed design stage.

This analysis is for the purposes of comparing systems. For the detailed design stage more data are needed and many of the figures used will need to be confirmed.

A3.9.5 Considering interest rates

Section 10.3 discusses depreciation and interest payments. If interest is to be taken into consideration in determining the equivalent annual cost of capital investments, equation A3.1 can be used. This calculates the annual payment that must be made each year during the economic life of the asset so that the loan and the associated interest are paid off at the end of the period. This process is known as amortisation and is used when there is a commercial loan to pay off or if the opportunity cost of the capital is to be taken into account.

Equation A3.1

$$A = P \times \frac{r\,(1+r)^n}{(1+r)^n - 1}$$

where: A is the annual payment,
P is the principal, the sum borrowed
r is the interest rate as a decimal
(i.e if the interest is 7%, r = 0.07)
n is the duration of the loan

Some values for the annual repayment are shown in Table A3.1, for different interest rates and for a relatively short-term loan (5 years for the compactor trucks) and a longer-term loan (20 years for the transfer stations).

Table A3.1 shows that high interest rates can have a significant impact on annual repayments, especially for long loan periods. If a comparison is being made, capital costs are a major part of the total costs, and the unit costs calculated with straight line depreciation are very close, the interest rates may decide which option is cheaper. However, if no interest is actually being paid, it may be more appropriate to consider actual expenditures and ignore interest.

Table A3.1 Annual repayments

Interest rate	Loan period Capital sum	Trucks (5 years) ♍ 5,859,000	Increase in annual repayment	Transfer station (20 years) ♍ 1,728,000	Increase in annual repayment
0% Straight-line depreciation		♍ **1,171,800**	0	♍ **86,400**	0
2%		♍ **1,243,036**	6%	♍ **105,679**	22%
5%		♍ **1,353,281**	15%	♍ **138,659**	60%
10%		♍ **1,545,589**	32%	♍ **202,970**	135%

RECYCLING AND TREATMENT

A4

This book is concerned with the collection aspects of solid waste management. Therefore, it includes only a brief review of recycling and treatment because they affect the amount and nature of the wastes to be collected as well as the selection of the vehicles used to deliver the waste to the recycling or treatment facilities. The final stage in the solid waste management chain – disposal – is discussed in Annex A5, but is also referred to in this Annex because the option of treatment and disposal of residues is often compared with the direct disposal of all collected waste. There are always residues from recycling and treatment, and so in all cases consideration must be given to the establishment of disposal sites and the transporting of either municipal solid wastes or residues to these disposal sites.

A4.1 OVERVIEW

When the solid waste has been collected, where should it be taken and what should be done with it? What is the current status regarding recycling, treatment and disposal in low- and middle-income countries? How are decisions being made? How do methods of recycling, treatment and disposal affect the choices of waste collection equipment and systems? These are some of the questions that this Annex will try to answer. The information here is just an introduction, intended to set the context, make links with waste collection, and offer warnings. Sources of more detailed information are listed in the Bibliography, Annex A6.2.

As a first step, the present usage of the terms "recycling", "treatment" and "disposal" will be discussed. Then the methods and implications of recycling and treatment will be briefly presented. The last sections of this Annex will discuss issues related to the selection and sustainability of the various options, and review the implications for waste collection.

A strict definition of recycling limits the meaning to processes that convert materials reclaimed from waste into a more useful form. However, in common usage the term includes every step involved in returning waste materials to the economy, and this is the meaning used in this publication. The stages involved in recycling may include picking, transporting, trading, sorting, cleaning and processing. In some cases manufacturing may also be involved. Reuse of items for the same purpose as that for which they were originally used (such as drink bottles) is included. To these activities is added the recovery of energy from wastes for economic purposes. The term "resource recovery" is strictly more accurate, but less well-known. Examples of recycling will be given in Section A4.2.

The treatment of solid wastes includes any processes that are implemented to reduce the costs of transporting or disposing of wastes, and any processes that reduce the risks posed by the wastes. There are clear overlaps with recycling. Composting can be regarded as recycling when there is a market for the product, and as treatment when the purpose is to reduce the pollution arising from the disposal stage. *Incineration* is generally regarded as treatment, but can be considered as a resource recovery process when energy from the burning of the waste is put to economic use.

Disposal is putting waste in its final resting place. There are two basic options for disposal and it is important to understand the distinctions between them. The most common method is open or crude *dumping*, and this involves unloading the waste on any piece of available land and doing nothing to reduce the environmental impact (in terms of air, water and soil pollution, and aesthetic degradation). A much better method is *sanitary landfilling*, which involves careful selection and preparation of the site where the waste is unloaded, controlled operation and final restoration of the site so that, in its final state, it blends with the landscape and causes no pollution. Measures are taken at all stages to minimise air and water pollution, and nuisance to neighbours. Sanitary landfills can be used to fill holes below ground level or form hills higher than the surrounding ground. Intermediate stages between crude dumping and full sanitary landfilling are called controlled dumping or managed (or engineered) landfilling.

Recycling by the informal sector is usually very different from the attempts of the formal sector. The principal motivation for recycling by the *informal* sector is economic – the need to earn money to buy food and other necessities. The motivation for recycling, treatment and disposal by the *formal* sector is more complex, and often lacking in developing countries. These two alternatives are discussed in more detail in Section A4.2.1. Success or failure in solid waste collection and street sweeping is very obvious to voters, politicians and managers on a daily basis, and most municipal officials are aware of the need to provide effective collection and sweeping services – particularly in central districts and areas where influential people live. However, it is a different story with recycling (by the formal sector), treatment and disposal. It is often the case that very few of the citizens of a town are aware of what happens to the waste after it has been collected, and so there is much less public interest and political impact in relation to treatment and disposal. (One of the authors remembers a case in which the senior technical officer of a city administration – the person with ultimate responsibility for waste management – was unable to locate the site where the waste of his city was being dumped.) A further problem is that very few city officials understand the benefits of sanitary landfilling; they think that there is no alternative to open dumping. The consequence of this lack of understanding and interest in many cities is that very little attention is paid to treatment and disposal, and so no effort is devoted to improving these stages in the solid waste management chain.

There is a general trend for decision-makers to look to composting and incineration as the solution to their disposal problems. However, there have been many failures and disappointments in developing countries with both these processes so it is appropriate to take every opportunity to warn decision-makers about the implications of these methods of treatment.

A4.2 RECYCLING AND RESOURCE RECOVERY

A4.2.1 Various models

There are two main models of recycling.

- In countries where there is no financial support from government for unemployed families, it is common to find informal sector recycling, as has been discussed in Section 11.3. This is motivated by financial necessity and the people involved often have very little awareness of environmental concerns and issues. In many cities informal sector recycling has proved to be financially sustainable, since significant numbers of people have been working in this way for years, and there is no sign that the numbers are reducing. Environmental sustainability is more of a problem, since the actors involved often show very little concern for the impacts of their work on health and the environment.
- The other model is found in industrialised countries where there are committed groups of citizens who lobby for recycling in order to reduce the demand for natural resources and minimise quantities of waste requiring disposal. Their concerns are environmental, not financial. Governments have responded to this demand by instituting laws and financial instruments (such as a tax on landfilling), and requiring local governments and industries to meet targets for recycling and waste reduction. This recycling involves additional public expenditure and additional work from each householder (to segregate wastes into two or more streams), and these additional burdens are accepted by the public with varying degrees of enthusiasm.

One of the major causes of failures in solid waste management in low-income countries is the copying of systems from very different situations without taking sufficient consideration of local factors, so it is very important to be aware of the differences between these two models. It is a mistake to think that recycling is the same all over the world.

In addition to these two models, there is a third model that has been employed in low- and middle-income countries, but it has not been generally successful. This approach involves the formal sector – public or private – and relatively large mechanised plants. They are typically based around mechanised composting plants and are usually set up by the national government or by an international donor or lending agency. Such plants are usually justified by the large percentage of compostable (biodegradable) material in the waste stream or by reference to practice in industrialised countries. Their performance is often unsatisfactory because they are not suited to the characteristics of the local solid waste, because of inadequate maintenance of the mechanical plant, or because insufficient attention is paid to the quality and marketing of the compost that is produced. The sale of recyclable materials, such as metals and plastics, is often more worthwhile financially than the sale of compost, but insufficient to meet the costs of running the plant. Some experiences with operation by large international contractors have been more positive. Composting is discussed further in Section A4.2.5.

A4.2.2 Requirements for economic recycling

Most materials can – from a technical standpoint – be recycled, but not everything. Some plastics cannot be recycled, and some materials, in particular composites of two or more materials, are not recycled. Electronic equipment contains small quantities of valuable materials, but separating the various components is very labour-intensive and involves some health risks. In many cases materials that can technically be recycled are not recycled for financial reasons. Cleanness and purity have an important impact on the opportunities for profitable recycling.

Recycling is more likely to be successful when there are large quantities and dependable supplies, which are not too far from a processing factory, and in a form that can be transported economically. The material should not be contaminated, and should be as homogeneous as possible. There should be a dependable market for the processed material or products with reasonably consistent prices. Transport is often a major cost component – the distance that recyclables must be transported and the opportunities for reducing haulage costs may play a big part in determining if recycling at a particular location is to be financially viable. Because many recyclable materials have very low densities, it is often necessary to compress and bale materials, or shred them, in order to achieve reasonably economic loads on vehicles and, in some cases, to enable the materials to be exported. (For example PET plastics from drinking water bottles have been exported from Egypt to Thailand and China where they are used to make the padding in anoraks and other jackets, which are then exported, to Europe and the United States.)

At-source segregation can provide materials with less contamination and requiring less sorting, but the following points should be kept in mind when planning to promote at-source segregation:

- It is often better to focus on sources of large quantities of material where there is an institutional structure that can be used to encourage segregation, such as hotels, restaurants, supermarkets, factories and offices (but often these opportunities have already been taken by the informal sector or small enterprises). The segregation at such sources is likely to be better than the segregation performed by a large number of households, so the material will be more homogeneous.
- Promoting segregation in the home requires a large amount of awareness-raising – both information and persuasion – and even after considerable efforts the level of co-operation may not be high.
- Consideration must be given to motivation. Paying cash for recyclable materials, exchanging cheap household items for recyclables and giving reductions in utility bills have all been used to motivate the public to segregate their wastes. It may be difficult to develop a simple method of assessing the monetary value of a mixture of many kinds of recyclable materials, in order to pay households for what they have segregated. Only in a few situations should enforcement by the local authority or the police be considered.
- There must be a means of separate collection for the segregated items – either one vehicle with separate compartments or different vehicles at different times for different wastes.

Most industries that buy materials derived from solid waste require large quantities and consistent quality. The individuals who collect or sort waste cannot collect large enough quantities on their own, so they must pool what they have recovered with that of other individuals. This is usually done by selling to middlemen or dealers. These dealers who buy recyclables from collectors and waste pickers generally have a bad reputation because they are accused of exploiting those who sell to them, paying low prices to gain a large profit. In some cases they may control the market, so that collectors are not free to sell to others for a better price. Some middlemen assist collectors by renting carts to them and providing loans. Middlemen may also have good contacts and know the business well so that they are able to operate more sustainably than newcomers to the trade. Waste pickers sometimes join together to form a co-operative in order to pool and sell what they have recovered.

A4.2.3 Environmental aspects

It is often assumed that recycling is always good for the environment, but this is not always true, and in some cases the environmental authorities may be obliged to prohibit some forms of recycling.

There are often clear environmental benefits resulting from recycling, such as:

- Reduced quantities of materials requiring land disposal or incineration, so that the air or water pollution associated with solid waste management are reduced, and less land is required for waste disposal.
- Reduced consumption of resources (such as petroleum or copper ore) because of the replacement of virgin raw materials with recycled materials,
- Reduced consumption of energy, since the reprocessing of recovered materials (such as glass or aluminium) requires much less energy that when virgin raw materials are used
- Improved waste collection services (for instance, waste pickers collecting paper and cans lying in the street, or waste collection services being largely funded by income from the sale of recyclables).

However, in any particular situation, consideration must also be given to possible health and environmental problems. The main problems resulting from informal sector recycling have been listed in the section on the informal sector. Recycling by the formal sector can cause the same problems, but good management and supervision can greatly reduce the risks. Monitoring of informal sector operations is much more difficult because they are not found on official records, occur on a small scale, and are often intermittent. (For example, some recycling processes that produce a lot of smoke are operated only at night so that the smoke is more difficult to detect.).

In weighing up these considerations, it must be remembered that informal sector recycling provides a livelihood for large numbers of citizens in many urban areas, thereby making a significant impact on the local economy.

A4.2.4 Issues of ownership

The organisation that collects waste may claim ownership of all waste, and not allow others to recycle parts of it. In the case of at-source segregation it may be argued that recyclables that are kept separate never enter the waste stream and so are not the responsibility of the agency responsible for solid waste collection. The failure to resolve this issue can lead to disputes and unhelpful competition. In some cases legislation defines the ownership of waste.

Recyclable materials that are put out in the street for collection by an official agency may be taken by others before the official collection service can pick them up.

An organisation (such as a co-operative or an NGO) may invest considerable resources into organisational arrangements and public awareness campaigns in order to set up at-source segregation and a separate collection scheme for segregated recyclables. However, such activities may not ensure ownership of the recyclables and it may happen that other people are picking up some of the recyclables before the collectors who are working with the particular organisation.

Various proposals have been made for sorting facilities that would be staffed by informal sector people working for themselves. Often the problems of dividing up the reclaimed materials are not considered. A co-operative is one solution to this problem, but waste pickers who are accustomed to working alone may have difficulty in adjusting to sharing the results of their work with others. (This is discussed in connection with transfer stations in Section 8.2.6.)

A4.2.5 Particular examples of recycling

a) Composting – In some situations farmers simply take organic wastes back from the markets when they bring their vegetables for sale and use this waste without any processing to improve the quality of their soil. This procedure helps to maintain the value of the soil, but can reduce short-term crop yields (because nitrogen is taken by the decomposing waste) and result in other nuisances (such as the presence of glass and plastic in the soil). Composting provides the same benefits without these drawbacks. Composting is the converting, by aerobic bacteria, of biodegradable wastes (such as food waste) into a good soil conditioner. Another benefit of composting is that it reduces the amount of biodegradable wastes in the waste stream, resulting in less pollution. Viable composting depends upon there being a ready market for the composted material within a short transport distance from the composting site, and this in general rules out large composting operations in favour of small-scale local composting where there is a market for compost in urban horticulture or local farming.

In general, mechanised composting has not proved sustainable in developing countries due to the high costs and short life of the equipment, as well as the problems of finding a market for the compost large enough to justify a mechanised operation. However, small-scale manual composting of selected wastes (typically market and abattoir wastes) can be viable. The equipment requirements at this scale are only hand tools and some means of transporting the waste to the composting site and the composted material from the site to the user. General municipal solid wastes often contain large quantities of *contrary* materials, including road sweepings and contaminants such as broken glass and plastics, which are not suitable for composting.

There is a tendency to think of compost as a valuable fertiliser. In fact, its fertiliser value in the form of the three main fertilising elements – nitrogen (N), phosphorous (P) and potassium (K) – is quite low. The nutrient value can be boosted by co-composting with sewage sludge, but local farmers may be reluctant to accept compost containing human excreta. The real value of compost lies in its qualities as a soil conditioner which retains moisture in sandy soils, and makes heavy soils easier to work.

It is often assumed that there is a demand for compost in a particular place, when in fact there may be none. Any existing demand for compost can be quickly undermined by concerns about toxic metal content and by the presence of fragments of glass or plastic. Because it is often a slow process to develop the demand for compost, it is advisable to start composting on a small scale and increase production in line with demand.

b) **Vermiculture** uses earthworms to produce a high quality soil conditioner. It is most suited to small-scale operations and the conditions must be controlled very carefully.

c) **Energy recovery** – Untreated solid wastes are burned in large incinerators to get energy, and wastes after processing into refuse-derived fuel (RDF) are burned in industrial applications. Before attempting either process it is essential to investigate very carefully the moisture content and composition of the waste (after it has been picked over by informal sector recycling workers) in all seasons because the energy value of some wastes is so low that incineration is not feasible. Huge sums of money have been wasted in low- and middle-income countries on unsuccessful incinerators and RDF plants. (See also section A4.3.1 below.)

The other means of gaining energy from solid waste is to allow the biodegradable fraction to decompose in the absence of air. One of the products of this process is methane gas, which can be used as a fuel. If this process takes place in a large closed vessel or tank, it is called anaerobic digestion or biomethanation. Anaerobic digestion has been used successfully for many years for treating wastewater sludge, but experience with treating solid wastes is still in the early stages and there have been many failures. Particular problems with solid wastes are caused by their heterogeneity – the wide variety of constituents found in the wastes – and their variability.

A more successful means of recovering energy from solid waste is in the capture of landfill gas (containing methane) at large sanitary landfill sites which are well constructed and well operated.

A4.2.6 Implications of recycling for collection systems

Sometimes informal sector recycling subsidises informal primary collection services. In some cases informal sector workers who collect wastes from houses and businesses can afford to charge only a small fee because they earn most of what they need from the sale of recovered recyclables, and because they do not take the rejects to a sanitary disposal site, thereby avoiding the tipping fee and the cost of transport. Formal sector collection services that transport wastes to sanitary landfills may need to charge significantly more. Informal collection services may operate only in the more prosperous sections of a city, where the waste has more value.

Mechanised systems of storage and collection (which are chosen because they are more hygienic and efficient) may reduce recycling since loaders have no contact with the waste and access by informal sector waste pickers is reduced. Small transfer stations (Section 8.2.4) however can facilitate informal sector collection and source recycling by providing a nearby disposal point for the reject materials. (Note that the sorting should not be done at such small transfer stations because of their limited space and their location in congested areas.)

In many countries the official waste collection labourers spend a significant part of their time unofficially picking recyclable materials out of the waste that they are loading. This practice reduces slightly the volume of waste requiring disposal and provides some extra income for the labourers, but it may add significantly to the time taken to collect the waste, and thereby to the overall solid waste management costs. It is probably not easy to stop this practice.

At-source segregation of solid wastes requires separate collection. Separate collection may be provided by collecting different wastes at different times, but the interval between collections of biodegradable waste must not be so long that unpleasant smells and fly breeding result. There are vehicles which are fitted with two or more compartments which can be emptied individually. Such vehicles may carry relatively small loads since not all the compartments may be full on each trip. Trucks that carry different waste in various containers may also carry small payloads. Small payloads result in high unit costs. The best system in many situations may be to contract the collection of dry recyclables to small contractors or leave them for the informal sector.

Another option for at-source segregation may be to distribute plastic bags of a particular colour for biodegradable waste. When filled and securely closed, these bags can be put in a bigger bag, which also contains the other waste. During or after collection, the biodegradable waste bags may be separated from the rest by picking out all the bags of the particular colour and removing them from the other wastes. Since the wet, biodegradable waste is kept in a plastic bag, this sorting is more hygienic and efficient, and the other waste is not contaminated. However, any form of at-source segregation requires a major effort to inform and motivate the public.

Sorting of mixed municipal waste never seems to achieve a satisfactory quality of compost – there is always some glass, as small fragments, in the compost, and the presence of heavy metals, perhaps from dust, may cause concern. It is therefore often useful to collect waste for composting plants from only selected sources, such as markets, restaurants and hotels, and to ensure that undesirable waste, such as street sweepings, is collected separately.

Compaction of mixed municipal waste reduces the value of the waste for recycling because it forces wet biodegradable waste into contact with dry recyclables, such as paper, contaminating it, and making it more difficult and less hygienic to separate it. Therefore mixed waste destined for recycling should not be carried in compactor trucks.

Rotating drum compactor trucks (Section 7.8.4) break open plastic bags and mix the waste by their rotating action. This is likely to shatter all glass items in the waste so that, if the waste is to be composted, it will be impossible to remove all the glass. Manual sorting of this homogenised waste is very difficult.

Transfer stations (Chapter 8) may be suitable locations for sorting the waste to remove materials that can be recycled. (As already mentioned, small transfer stations [Section 8.2.4] in crowded areas are not suitable places for sorting wastes.) Since transfer stations are often close to residential areas, they should be designed so that they can be cleaned quickly and effectively at the end of each day. No materials should be stored on the site overnight.

Hazardous healthcare wastes from hospitals, clinics and other medical facilities need special treatment. They pose a much higher risk than municipal wastes because they are particularly infectious. The most dangerous wastes are syringes and other medical items fitted with needles, because they may contain infected blood and can easily puncture the skin. Unfortunately some components of these hazardous wastes attract a high price for recycling, and needles and syringes may be sold as toys or packaged and resold for use in medical treatment by illegal and unscrupulous practitioners. If these wastes are not treated at the hospital where they are generated it is necessary to develop secure means of transporting such wastes to the place where they are treated or disposed. Security can be guaranteed by using transportation that keeps these wastes in a locked chamber or container – if there is also careful supervision of the collection and transport operations.

A4.3 TREATMENT OF SOLID WASTES

The purpose of treatment of solid wastes is to reduce the costs of transport or disposal, or to reduce risks to health and the environment.

A4.3.1 Incineration

Incineration is the burning of solid wastes at high temperatures in enclosed chambers under controlled conditions so that air pollution is minimised. The flue gases are cleaned to remove suspended particles and acid gases. The volume of the solid residues after combustion is likely to be less than ten percent of the volume of the incoming waste, and these residues do not attract flies or vermin and do not decompose. However the ash may concentrate toxic heavy metals and contain soluble components which can pollute water. Inadequately designed and poorly operated incinerators can cause dangerous air pollution. Incinerators are used for municipal wastes and for selected hazardous wastes. The processes are expensive in terms of capital costs and operating costs, and require high standards of operation and maintenance.

a) **Incineration of municipal wastes** – Incineration of municipal solid waste should not be attempted in low- and middle-income countries, not only because of the costs, but also because the wastes generally have a low energy value due to their high moisture content and the prior removal of paper and plastic by waste pickers. If the waste has a low energy value, it is necessary to add fuel (usually oil) in order to keep the wastes burning, and if the temperatures are too low it is likely that unacceptable air pollution and damage to the incinerator will result.

   Large scale incineration should not be considered without a full-scale analysis of the wastes and a full engineering feasibility study. In order to demonstrate the unsuitability of the wastes, it may however be necessary to carry out an initial assessment of the wastes to show that the net calorific value (NCV) of the wastes (in particular during rainy and watermelon seasons) is insufficient to support full combustion and offers no possibility of energy recovery.

b) **Incineration of hazardous wastes** – There are two kinds of hazardous wastes for which incineration may be recommended.

   - Hazardous healthcare wastes (already mentioned at the end of Section A4.2.6) require special treatment because of the associated risk of infection. These hazardous wastes are only a small proportion – perhaps 20% – of all wastes coming from healthcare establishments, so it is important to keep the hazardous wastes segregated from other waste so that incinerators for treating them can be small and costs are minimised. These incinerators usually have two chambers in series, and should operate at a temperature of at least

800°C, but often they are not operating correctly, or not at all. It is essential to have a contingency plan so that hazardous wastes continue to receive effective and secure treatment and disposal when the designated incinerator is not operational. Sometimes costly incinerators are not used to save the cost of the fuel. There are also other ways of treating hazardous healthcare wastes, notably steam sterilisation.

- Hazardous industrial wastes can be very toxic and polluting if they are not managed carefully, however only a small proportion of industrial wastes are hazardous. The incineration of hazardous wastes is very expensive indeed, so it is essential to ensure that all wastes treated in this way are hazardous materials that require incineration. Special high-temperature incinerators are used. It is also possible to burn hazardous organic wastes in cement kilns. (It is very important that no wastes containing hazardous heavy metals are incinerated. Such wastes should be treated chemically before disposal at special landfill sites.) Many countries have comprehensive tracking systems, recording each stage of the collection, treatment and disposal chain. The purpose of such systems is to ensure that hazardous wastes are not disposed with municipal waste but receive the necessary treatment, which is much more expensive than the methods used for municipal wastes.

Hazardous healthcare and industrial wastes are not included in municipal solid wastes, so they are not discussed further. However they both require special equipment, special legislation and enforcement, and special management techniques. The generator of hazardous wastes should be held responsible for ensuring that their transport, treatment and disposal are according to the requirements of law.

In some industries non-hazardous waste from one industry may be used by another industry as raw materials.

A4.3.2 Baling

Baling involves compressing solid waste into large cubes, with a volume of about one cubic metre. The process requires powerful hydraulic presses and special lifting equipment. It is said to reduce transport and disposal costs, and require less space in landfills. Baling of general municipal waste is very unlikely to be economically worthwhile in low- and middle-income countries because of the cost of the equipment and the high initial density of the waste. Furthermore, waste with high contents of biodegradable material decomposes in landfills to settle to a very high apparent density, so baling is likely to achieve very little in terms of saving landfill space (and therefore extending landfill life) in such circumstances. However, small balers are commonly used for recyclable materials such as plastics, paper, cardboard, and aluminium and steel cans, to reduce their volumes for transport.

A4.3.3 Size reduction

Size reduction means cutting or pounding the waste so that larger lumps or pieces are cut or broken into smaller ones. This can be done using various kinds of equipment, including hammermills, rotating drums and shredders. Reducing the particle size in this way allows more waste to be contained in a particular volume (which might save transport costs) and helps to accelerate microbiological processes such as composting. Hammermills have high demands for electric power and both hammermills and shredders require considerable maintenance. When the high initial density of municipal solid wastes in most low- and middle-income countries is taken into account, there is very little reason for size reduction just for the purpose of increasing bulk density. Hammermills and shredders may have a useful role in the recycling of materials such as glass bottles and certain plastics.

A4.3.4 Implications of treatment for waste collection systems

If waste is taken to an incinerator for treatment, the distance over which it must be carried is likely to be less than the distance to a landfill, since the incinerator is likely to be closer to the urban area where the waste in generated, and the vehicles will not need to be suitable for driving on rough and soft ground (as found on landfill sites). The transporting of ashes from the incinerator to the disposal site will require only a small capacity.

Hazardous wastes – whether healthcare or industrial – are normally transported in containers which are carried in a closed box-type body, often fitted with a platform hoist to aid loading and unloading of heavy containers.

A4.4 REFLECTIONS ON DECISION-MAKING PROCESSES

On an international scale, it is not possible to generalise about how decisions regarding recycling, treatment and disposal are made. There are, however, some indications that the following attitudes or beliefs contribute to the making of unwise decisions in the fields of solid waste recycling, treatment and disposal.

- **The desire to be modern** – Such attitudes could be characterised as "We want the best", "We must have the same as Switzerland (or Sweden or…)", or "Sophistication is always desirable". These attitudes may stem from a belief that waste management is the same the world over, and that differences in waste characteristics, labour costs and affordability have no impact on the suitability of technology. Decisions favouring modernity in this way may be made after visits from unscrupulous salesmen with persuasive words offering various kinds of inducements to buy their particular type of equipment. In other cases local authority officials who have been taken on a study tour in a foreign country arrive back at their place of work determined to introduce what they have been shown during their trip, and they may be reluctant to consider alternatives. However, almost inevitably, sophisticated equipment from the industrialised countries has high operating and maintenance costs in developing countries and depends on costly imported spare parts with long delivery times.
- **Other systems have been tried and failed** – Some decision-makers may look for a new approach because an old one has been tried and is considered to have failed. For example, there may have been a composting plant in the area, which failed for one reason or another, and so the decision-maker does not investigate the reasons for failure, but looks for a new technology (which, if it is more sophisticated, is even more likely to fail). Similarly, a city that has experimented unsuccessfully with sanitary landfilling, instead of investigating the cause of the problems, considers sanitary landfilling to be unfeasible as a solution and so invests heavily in incineration. If the expertise and other resources could not be found to operate a sanitary landfill, it is very unlikely that they can be found to operate an incinerator successfully.
- **We can make money out of this** – The idea that garbage can be turned into gold intoxicates some people. They see the informal sector workers making a living from waste recycling, and they think that they can become rich or that the solid waste management services can be funded from the proceeds of recycling. Contracts are written so that operators of recycling plants must pay for the wastes that they take. Experience suggests that it is very difficult to fund the operation of large-scale recycling plants merely from the sales of recovered materials.
- **Don't worry about operation** – Many good sanitary landfill sites have been constructed, but they have quickly degenerated into burning dumps because no money and no thought have been invested into the operations stage. The motivation, knowledge and seniority of the landfill manager are crucial to the successful operation of a sanitary landfill. Huge sums may be invested in setting up recycling and treatment plants, but if the operation stage is poorly prepared and maintenance is neglected, no lasting success can be expected. There must be a reliable and sufficient budget provision for all operating costs, including maintenance and replacement of machinery, and a motivated and trained site manager (who is willing to spend almost all of his/her working time at the site) must be appointed.
- **Foreign money? No problem** – Recycling and treatment plants are often set up with foreign money, either from private companies or governmental development agencies. Because the plant apparently requires no local finance, the decision-makers pay very little attention to the viability of the scheme. Soon the costs become obvious. Operating and maintenance costs are more than were expected. Penalty clauses for failing to deliver the right kind or quantity of waste are applied. Even if there are no financial costs, there is likely to be a drain of skilled staff away from the main solid waste management services to the operation of this plant. As the saying goes, there is no such thing as a free lunch. And the term "soft loan" should make alarm bells ring. Even if the loan is "soft", the principal must be repaid, and to the small rate of interest must be added the additional costs caused by any depreciation of the local currency against the currency of the loan. The operational experiences with large recycling and treatment plants, and the lack of commercial success of such plants, suggest very strongly that the plant will not generate the rate of return forecast in the feasibility study. Even if the finance is coming from overseas, the proposal should be scrutinised carefully.
- **Anybody can decide** – A final problem is that decisions on waste management equipment often seem to be made by senior decision-makers without reference to the technical people who run the solid waste management system, or to consultants with practical know-how. The belief seems to be that solid waste management is a very simple affair that we all understand, and that anyone can make a good decision about what equipment is needed. The fact that there are so many failures in solid waste management suggests that it is not so simple.

DISPOSAL OF SOLID WASTE

A5

A5.1 INTRODUCTION

As already mentioned there are two extremes in waste disposal – crude or open dumping and sanitary landfilling. There are also intermediate steps in which some, but not all, of the beneficial practices of sanitary landfilling are implemented. Such intermediate steps may be referred to as controlled dumping and engineered landfilling.

In spite of the efforts of engineers and various international and bilateral organisations to promote sanitary landfilling, it is still regrettably true that there are very few good sanitary landfills in low- and middle-income countries. Some possible reasons for this state of affairs have been suggested in Section A4.5.

The techniques of sanitary landfilling have been developed over decades, and are still being improved. Providing details of these techniques is not within the scope of this book. Only a brief introduction to these disposal techniques and machines is considered appropriate here, together with some comments on the requirements of collection vehicles that deliver waste to disposal sites. More information on sanitary landfilling can be found in sources mentioned in the Bibliography (Annex A6.2).

Modern techniques of sanitary landfilling and the machinery that is commonly recommended for this purpose are appropriate for large sites which dispose of waste generated by populations at least in the hundreds of thousands There are, however, many cases where is it not economically feasible to transport waste to a large site. Towns that are relatively isolated from major cities need a method of landfilling that is appropriate to their size and resources and to the characteristics of the waste (as it arrives at the disposal stage after any recycling activities). This Annex includes details of a proposed method for operating small landfill sites. This method uses equipment that has been well tried in other applications, but this method of operating small landfills is still in the experimental stage, and still needs to be proved. The authors hope that one or more of the readers of this book will be able to take these ideas and develop and prove them in practice.

A5.1.1 Open dumping

Although by far the most common disposal method in many countries, open dumping causes many problems. Waste is unloaded wherever the driver of the collection truck finds a convenient space. Access to parts of the site may be blocked by piles of waste, accumulations of water or rough terrain. Usually there are many smouldering small fires. These fires may be started by waste pickers for various reasons or by municipal employees in an attempt to discourage fly breeding and reduce the volume of the waste. Neighbouring householders may light fires to control the insects and rats. Some fires may also start as the result of natural processes, scraps of glass focusing the suns rays, or the depositing of burning loads. Fires should not be tolerated because of the health impacts of inhaling smoke, particularly the toxic dioxin and furans gases generated by the burning of certain plastics[47]. Smells from putrefying wastes add to the smoke problems. The decomposing wastes produce noxious liquid, known as leachate, especially during rainy seasons. This leachate flows into streams and groundwater resources, contaminating water supplies. Scavenging at the dumpsite is a hazardous occupation for the waste pickers, particularly where dangerous medical wastes (such as blades and items with needles) are mixed with the general municipal wastes.

A5.1.2 Controlled dumping

It is often difficult to change from open dumping to sanitary landfilling in one step. In many cases it is more appropriate to gradually upgrade disposal operations, developing expertise and demonstrating to decision-makers that there is an alternative to open dumping. The first step in controlling a dumpsite should be to stop all fires at the site. (This might be very difficult to achieve if the waste pickers are determined to keep burning the waste, but it is essential.) The next step might be to improve access to the site by developing or upgrading the site roads and levelling the waste so that the trucks can drive over it. Covering the waste with soil will help to reduce the numbers of flies and birds, and improve the appearance of the site. In some cases – where there is a low risk of water pollution because of the climate, natural soil strata,

47. In a typical situation, a survey of a small village downwind from a burning dumpsite in Egypt showed that 92.1% of the villagers felt that the adjoining dumpsite affected their health and 89% indicated that they suffered from some form of respiratory disease. This clearly indicates the very serious hazards caused by burning wastes at low temperatures. Source: SEAM Solid waste management case study, Sohag City, 1999 topography, distance to water sources and the depth of the water table – this may be a satisfactory option for smaller communities. The key to the success of such upgrading activities is the site manager – if (s)he understands the reasons for the required improvements and has the motivation and authority to implement them day by day.

A5.1.3 Sanitary landfilling

The objective of sanitary landfilling is to dispose of solid waste in a way that causes minimum impact on the environment, and at minimum cost. In order for the operation to be economical, the site must be well managed so that the maximum amount of waste can be placed on the site. The four stages of sanitary landfilling are site selection, site preparation, operation and post-closure management.

a) **Site selection** – The site for a new landfill should be selected carefully, taking into account topography, geology and water resources, land use, distance from the centres of waste generation, transport routes linking the site to those centres, and distance from housing and airports. It cannot be expected that the nearest residents will welcome the site, but it is important to secure their acceptance.

   There are often clear economies of scale with landfills – the cost of disposing of one ton of waste at a particular landfill is lower if more waste is disposed there. Sanitary landfilling needs good management, and it is easier to find a good site manager for one large site than five good managers for five small sites. These are the two main reasons in favour of large regional landfills that serve several cities and towns. Clearly it is necessary to factor in the costs of transporting the waste when a regional landfill site is being considered.

   Although large regional sanitary landfills offer clear advantages in many cases, there are many situations in which the haul distances are too great or there is strong political opposition to accepting waste from another state or community, and so it is necessary to construct and operate a site that is too small to be operated in the same way as a large sanitary landfill. Keeping in mind the basic objectives and requirements of sanitary landfilling, operating procedures should be developed, using specially adapted equipment or sharing equipment with other municipal departments, so that the environmental objectives of sanitary landfilling can be achieved at a reasonable cost. Section A5 4 below describes an innovative new approach for operating small sanitary landfills.

b) **Preparing the site** – There are many factors to consider when designing and constructing a landfill site, but the primary issues are water pollution and operational efficiency. Polluted water from the waste is prevented from reaching water resources by an impermeable layer which may be a natural clay bed below the site, or an artificial barrier constructed using imported clay, plastic sheeting, bitumen, or soil mixed with bentonite. The polluted liquid or *leachate* that is trapped by the impermeable barrier is collected by a drain system and treated[48], so that only relatively clean water is discharged to the environment. As much as possible, surface runoff is prevented from reaching the waste in order to minimise the quantity of water that becomes polluted. Because a sanitary landfill must include a leachate-retaining barrier, it cannot be constructed on an existing dumpsite, unless there is a naturally impermeable soil barrier and a means of collecting leachate before it can escape from the site. It is usually a major undertaking to upgrade existing open dumps or even controlled dumps into sanitary landfills. Construction can be phased, and, when divided by the total tonnage of waste received and expressed as a unit cost, the cost may not be very high, but it represents a significant capital expenditure and is, in most cases, an additional cost that has not been paid before.

c) **Operations** – Continuous compaction of the wastes in the landfill makes the best use of the void space and promotes decomposition. Compaction and daily covering of the wastes controls smells, insects and rats. A high standard of management is required with strict control of the types of wastes reaching the landfill. Large amounts of daily cover material are required, involving the excavation, transport and spreading of this material. Gas emissions from the decomposing wastes (mainly methane and carbon dioxide) are collected and can be either burnt on-site or (in the case of large landfills) used as a fuel source for running vehicles or generating electricity.

d) **Post closure management** – When the site is closed to further incoming loads of waste, it must be restored to a natural appearance. The waste will continue to decompose and settle for some years, generating methane and leachate, so it must be monitored and any necessary corrective action taken.

48. *Leachate may be treated on-site, tankered away or pumped to a municipal wastewater treatment plant, recirculated to the deposited wastes or allowed to evaporate in lined basins.*

A5.2 WASTE DISPOSAL STRATEGY

Waste disposal sites are generally at some distance from the urban areas that they serve, so they may be ignored or forgotten and not be accorded a high priority when budgets are being prepared. Although the unit costs may be significantly below the unit costs of collection, it may be difficult to find the additional allocation and to raise the necessary capital. Even a half-way measure towards a controlled and well managed dump may be a big step towards relieving an existing hazardous and unhealthy situation.

Water pollution is an issue that needs clear thinking.

- It is often assumed that leachate is caused only by rainfall, and so leachate control measures are not installed in landfills built in arid climates. However, experience in the middle area of the Gaza Strip (which has a semi-arid climate) suggests that much of the wastewater known as leachate actually originates in the waste itself, and is released by the compaction and microbiological decomposition of the waste. If the waste is dry (because food waste has been removed to feed animals) and rainfall is minimal, there may indeed be little leachate.
- There is no benefit in collection the leachate if it is not treated effectively. Often great attention is paid to the liner and drainage system and little to the management of the leachate that is collected by these features, so that the leachate is released in a concentrated (point source) flow rather than being dispersed over the whole area of the landfill (thereby allowing the possibility of some natural treatment if the soil conditions are favourable). Leachate is difficult to treat, so evaporation and recirculation are attractive options, provided that the resulting odours do not become a cause of public opposition.
- The concentrations of polluting heavy metals in the leachate may be low if there are no industrial residues that contain heavy metals, or high if certain industries (such as electroplating and paint factories) send their wastes to the site.

There is a tendency in developing countries for the environmental protection agencies to introduce legislation based on advice from overseas environmental consultants who recommend standards equivalent to those imposed in the more industrialised countries where only full sanitary landfilling is acceptable. As a result, in many situations where new landfill sites are being considered, the high-cost proposals put forward are simply beyond the means of the local authorities and the willingness to pay of the householders. The standards are unenforceable and unsustainable. Consequently nothing gets done and the existing open dump sites continue to cause pollution and ill-health. A gradual improvement is certainly preferable to no improvement, but sometimes environmental regulations or standards demanded by development co-operation agencies prevent improvements being made and instead maintain the status quo.

Waste disposal strategies should take into account local financial and human capacities and direct efforts towards making realistic and sustainable improvements, even if the ideal cannot be achieved in the short or medium term.

A5.3 EQUIPMENT FOR OPERATING LARGE LANDFILLS

For both controlled dumpsites and for sanitary landfills, mobile equipment is required for the purposes mentioned below. Some of the equipment mentioned is shown in Figure A5.1.

a) **Preparing cells** – Landfill sites are usually divided into cells, one main cell being filled before the next is started. Cells may be formed by excavating them or building an earth bund around the perimeter. Excavators, wheeled loaders or tracked loaders are used to excavate or construct cells and stockpile cover soil, but on smaller sites they are not needed all the time so they can be brought in for cell construction as needed.

b) **Spreading the waste material** – using a bulldozer, tracked loader or a landfill compactor. To enable the wastes are to be compacted, they should be placed is layers less than 50 cm thick.

c) **Compacting and levelling the wastes** – The wastes are compacted to reduce the amount of void space required, and to control insects and rodents. This is normally done with a very costly landfill compactor which is specially designed for this purpose, or a bulldozer pulling a sheepsfoot roller. (A similar result can be achieved, although not as efficiently, by running a bulldozer or tracked loader backwards and forwards over the wastes a number of times, but the pressure exerted by a tracked vehicle is low, because the weight of the machine is spread over a large area by the tracks. However this can result in considerable maintenance costs associated with, for example, high track wear.)

d) **Spreading cover material** – to prevent litter blowing and to prevent flies and rodents breeding in the wastes. Standard landfilling practice is to cover the compacted wastes every day with a thin layer of soil. This involves excavating and transporting soil from a nearby source. Wheeled loaders and tipping trucks are commonly used for this purpose. Bulldozers are usually used for spreading and levelling the cover soil, but large landfills may use motorised or towed scrapers and motor graders. Again, all of these machines are costly to buy, and to operate.

e) **Constructing and maintaining site roads** – is an important function to ensure that trucks can travel on the site without difficulties or damage. A grader is useful for this purpose.

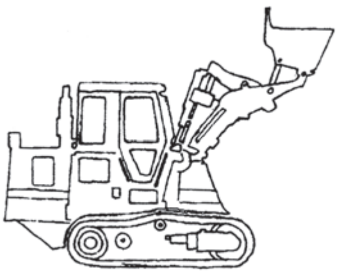
f) **After each cell is filled** – it is covered with a temporary or final cap, which is usually made to be impermeable by means of clay or a plastic membrane. Topsoil is spread on the final cap and seeded to promote the growth of vegetation which stabilises the soil.

Stationary equipment such as a weighbridge, office facilities, pumps, lighting, gas control equipment and wastewater treatment systems are also required, but will not be discussed here.

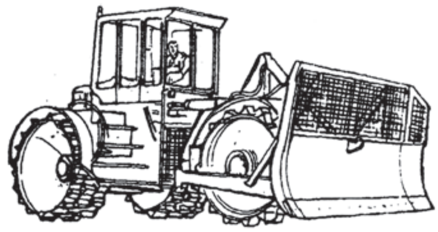
The maintenance of the machinery used on landfill sites is of crucial importance and should be managed according to the principles of planned preventive maintenance that have been presented in Section 9.5 and Annex A2.

It can be seen from the above that the preparation, operation and closure of a landfill are costly processes requiring expensive equipment and high standards of management. The equipment required typically costs a minimum of US$ 200,000 (2008 prices) for even a relatively small landfill using only a single tracked loader. (This kind of machine is capable of handling up to 200 tons of wastes per day, but a second machine will also be required as a backup in case of breakdowns.) It may be necessary to spend more than US$ 1 million (2008 prices) on the equipment that is required for larger landfills.

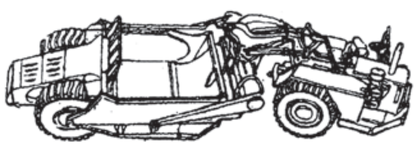
All of the equipment used for these purposes can be obtained in a range of sizes, their costs depending upon the weight and the engine power of each machine. If several different types of machines are required, the total equipment costs can be very high. The selection and specification of the equipment to be used depends upon the



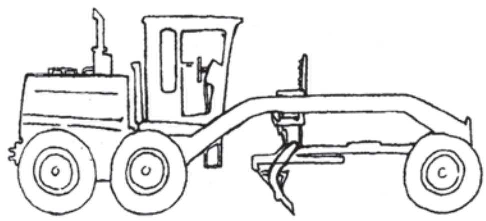
Tracked loader



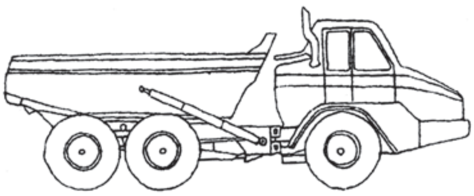
Landfill compactor



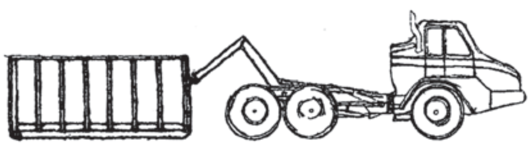
Scraper



Grader



Articulated off-road dumper



Off-road hooklift vehicle

Figure A5.1 Machinery used on a large landfill site

size of the landfill (in terms of tons of wastes deposited per day). A medium-sized landfill might have only a small tracked loader with a multipurpose bucket and blade, other equipment being brought to the site from time to time. A very large site might use most of the machines shown in Figure A5.1, together with a wheeled loader and a 360° tracked excavator.

A controlled dumpsite may require mobile equipment only once every three days or so, and existing local authority road-making equipment may be sufficient for the construction of a small or medium-sized disposal site. Operations can be maintained using a general-purpose tracked loader which is brought to the site every three days. However, sanitary landfilling requires that the wastes must be spread and covered every day, necessitating that some equipment must be available on-site every day, with backup equipment to cover servicing and breakdown periods. Careful selection of units that can perform several functions can help to reduce investment costs, but the purchase of equipment conventionally required for even a small sanitary landfill site is beyond the means of many municipalities.

A proposal has been put forward by one of the authors for a low-cost landfill operating system for small sanitary landfills. Operations are carried out using an agricultural tractor in conjunction with a number of attachments and a tipping trailer, so it can perform all of the landfilling functions listed at the beginning of this section. This proposal is described next.

A5.4 PROPOSED SYSTEM FOR USING AGRICULTURAL TRACTORS TO OPERATE SMALL LANDFILLS

A5.4.1 Smaller cities and towns have been neglected

Most solid waste management studies for developing countries have concentrated on the larger cities, very little attention being given to the far more numerous small urban centres which often have combined populations greater than those of the larger cities. In Africa, for example, less than 20% of the population live in cities of more than one million people. However there are very many small towns and cities with populations of 20,000 up to 1,000,000 which together account for a larger population than the bigger cities.

These smaller towns are often the ones with the fastest growth rate and the least expertise to identify waste management systems which are appropriate to their smaller requirements. They generally ignore the problems caused by uncontrolled dumping of their wastes, after perhaps looking at the systems recommended for the larger cities and deciding that these systems are totally beyond their limited resources. If they do build a sanitary landfill (perhaps with equipment provided by a development aid agency) and attempt to operate it in the conventional way with expensive, high-powered machines, they may quickly become discouraged by the high demands in terms of operating cost and expertise.

Consultants working for the donor agencies usually recommend the same systems for the small towns as they have recommended for the large cities. These capital-intensive systems require large and costly machinery and trained landfill site managers who are not generally available in smaller towns or cities. The effect of all this is that the proposals put forward by the consultants and other experts are very seldom implemented or prove to be not sustainable in the long term. As a result, no lasting improvement in disposal is achieved.

In a typical low-income country each person generates between 0.2 and 0.4 kg of wastes per day. (These quantities vary greatly from country to country.) However not all of this waste reaches the collection vehicles. For the purposes of this illustration, the figure of 0.3 kg/capita/day will be used for the amount of waste reaching the landfill site. A small tracked loader with a multipurpose bucket and blade, together with a second backup machine, would be able to handle the wastes from a city of up to 600,000 people in a low-income country. There is however a need for a much less expensive system suitable for smaller towns and cities, such as a town of 200,000 people with a waste generation of perhaps 60 tons/day. No proven system for such a quantity of waste is presently available.

A5.4.2 Equipment for the proposed small landfill system

The proposal described here is a system based on a single agricultural tractor fitted with a number of attachments that enable it to undertake all the six functions listed in Section A5.3. Before describing this system in detail, it must be stressed that, at the time of writing, this innovative approach to small-scale landfilling has not yet been implemented. Initial trials were carried out in Egypt towards the very end of a programme when it was not possible to complete the trials. However each step of the system employs a proven technology and each of the processes and attachments used has been well proven under agricultural conditions so that no reason can be found as to why it would not be successful. It is recommended that this approach should be considered on a trial basis for small towns where conventional landfill equipment is not affordable.

The system is operated by the tractor and attachments described below.

a) Tractor – A 70–75 hp (52–56 kW) four-wheel-drive tractor with hydraulic lift arms (three-point rear linkage) and front ballast weights. The tractor is also fitted with an automatic hitch[49] for pulling a trailer and quick release hydraulic couplings for operating the attachments described below – a push-off buckrake, a grader blade and a front loader bucket. The driver should be shielded from strong sun and rain by a canopy or roof.

When operating on certain types of waste there may be the problem of frequent tyre punctures but this is not expected to be the case in most developing countries. If, however, the tractor suffers from many punctures, it can either be fitted with locally manufactured steel wheels, similar to those commonly used on landfill compactors, or the tractor tyres can be filled with polyurethane foam to make them puncture-proof.

b) Push-off buckrake – Push-off buckrakes were very commonly used in Europe for making grass silage (fermented grass used as cattle feed during the winter) during the 1970s and 1980s before the farmers changed to making baled silage. The push-off buckrake (Figure A5.2 and Photo A5.1) consists of a large platform of spring steel tines the full width of the tractor, and a blade that can slowly push material off the tines. A push-off buckrake can be attached in only one or two minutes to the tractor's standard three-point rear linkage by means of three pins and a quick-release hydraulic hose connection.

This buckrake can pick up and transport loads of up to 500 kg. In a small landfill it would be used to pick up waste from where it is unloaded from the collection truck and transport it to the working face of the landfill. The hydraulically-operated push-off plate would then slowly push the waste off the buckrake while the tractor is reversing and the waste would be compacted by the tractor rear wheels as they pass over it. The tractor front wheels then compact the wastes further. The tractor then moves forwards and backwards a few times, each time on a line which is the width of a tractor tyre to the side of the previous line. Each time the tractor passes over the waste it compacts the fresh waste directly under its wheels. Figure A5.3 illustrates a push-off buckrake and the method of its operation.

During the original trials in Egypt it was found that the 15 cm spacing of the horizontal tines on the standard silage push-off buckrake was too wide so that loose waste was falling down between the tines. Instructions

49. *The automatic hitch is used to pick up hydraulically and attach the towbar of a two-wheeled trailer.*

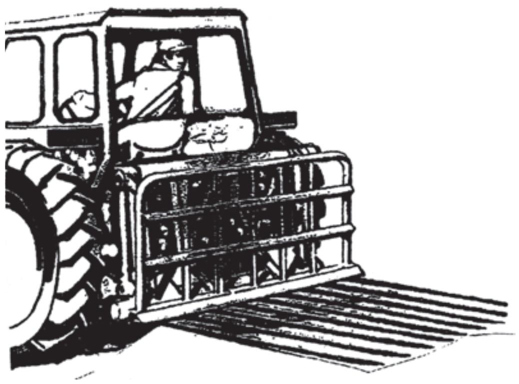


Figure A5.2 The agricultural buckrake for spreading wastes

Photo A5.1 The agricultural buckrake for spreading wastes

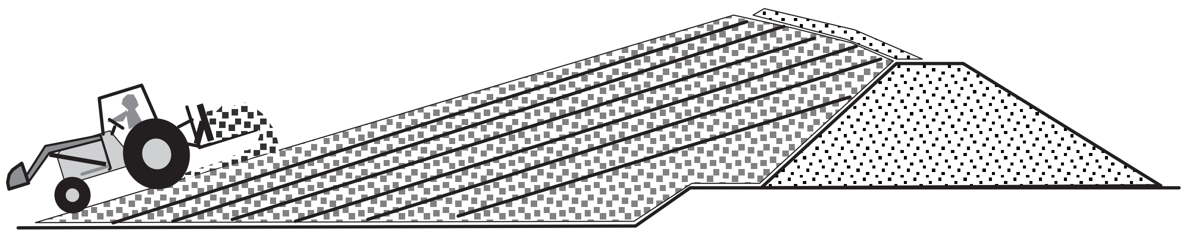


Figure A5.3 Spreading and compacting waste using a tractor fitted with a buckrake were given to add in additional tines but the project in Egypt ended before this could be carried out and the trials completed. An alternative would be to fabricate special buckrakes with tines at a spacing of 10 cm (between centres). Buckrakes are typically about 20 cm wider than the tractor.

c) **Front loader attachment** – The tractor should be provided with a heavy-duty front loader attachment with a digging bucket. This attachment will be used to excavate the cells, to load cover material into the trailer and to spread the cover material over the deposited waste.

d) **Trailer** – The most appropriate type would be a six ton capacity *scow-end*[50] trailer that is open at the rear and has a hydraulic tipping cylinder which can be operated from the tractor seat. This trailer will be used for transporting the cover material. The trailer should have only two wheels because two-wheeled trailers are more manoeuvrable than four-wheeled trailers and they transfer some of their weight onto the rear wheels of the tractor to improve traction on soft ground. The automatic hitch on the tractor enables the trailer to be dropped off and attached quickly when loading cover material using the front loader attachment.

e) **Grader blade** – A simple grader blade that can be attached to the tractor by the three-point rear linkage is used for levelling the daily cover after spreading and compacting the wastes, and for levelling and grading the final cover material.

Based on experience of using this system for making silage, it is estimated that this system should be able to spread, compact and cover up to 75 tons of wastes per day. Typically this would be the daily waste generation of a population of up to 250,000. However, it is considered that it would be more realistic to expect one tractor to handle the wastes of up to 200,000 people, to allow time for servicing and maintenance.

The site should have a secure enclosure or garage for housing the equipment and fuel storage.

The cost of this system would be about US$ 50,000 (according to 2008 prices), which is only a small fraction of the cost of the tracked loader system. As with every system, a second standby machine should be available to allow for breakdowns and servicing.

50. *A scow-end trailer has a floor which slopes upward at the rear end so that the load can be retained and tipped out without the need to operate a tailgate. For this purpose the trailer must tip more steeply and may need a double acting hydraulic cylinder to start lowering the tipped body while the centre of gravity is behind the hinge point.*

A5.4.3 Operating this system

Figure A5.3 shows the small landfill system in operation on an above-ground landfill. The area being filled has been excavated to a depth of around 1.0 metre and the excavated soil has been stored for use as cover material. The depth of excavation would depend upon the topography of the site, the permeability of the soil beneath the site, the level of the water table and the suitability of the excavated soil for use as cover material. The waste should be placed and compacted in layers about 20 cm thick to form a ramp with a slope of about 20 degrees. The waste is compacted by the tractor as it drives up and down the ramp.

If it is considered necessary to protect a water source below the site according to full sanitary landfilling standards, the excavated area can be lined with a clay, plastic or bitumen liner, or by mixing bentonite with the underlying soil, and installing a drainage system of gravel and coarse stones, and drainage pipes. In this case the depth of excavation may be reduced to permit gravity drainage to a collection sump or treatment plant.

Figure A5.4 shows a proposal for the rehabilitation of an existing dumpsite where burning wastes had been allowed to spread over a very large area. A cell about 30 m wide by 100 m long would be formed by making bunds (raised banks) from the burnt wastes already on the site. The long dimension should be in the same direction as the prevailing wind. At the downwind end an area about 30 m by 30 m should be excavated to a depth of about 1 m and the excavated material stored for use as cover. A temporary litter fence at the top of the bunds, made from a 5cm x 5 cm weld mesh, chain link fencing or netting, should be erected to trap blowing litter. The placing of waste would start at this end of the cell, building a ramp to a total height of 4 metres above the excavated level. As the fill progresses the excavated area is extended to provide more cover material. The finished height of the deposited waste should be greater towards the middle of the cell so that it sheds rainwater. When this first cell is full (after 1 to 2 years) it should be covered by clay and topsoil and planted with appropriate local plant species that will stabilise the soil. A second cell should already have been prepared and should be filled using the adjacent completed cell as one side.

In the location for which this system was proposed it was found that a goat herder was grazing his goats on the wastes. The grazing by the goats was greatly reducing the amount of organic material and the sun was also drying the remaining wastes so it was likely that very little leachate was being produced. It was therefore proposed that the goat herder should be employed as a site watchman and allowed to continue to graze his goats but on a strictly controlled basis. A low-cost agricultural electric fence could be used to divide the working area into two zones. During the day the wastes would be placed in one half of the working area while the goats were grazing the other half. After the last waste load of the day had been delivered and spread, the goats would be allowed onto both halves of the disposal area until the next morning. Then the goats would be moved on to the previous day's spreading area before further waste is spread on the area which they had just vacated. An elevated water tank and a fire hose should be available for extinguishing any fires as well as for watering the goats. The continuous spreading and compacting of the wastes in thin layers in a small area together with the grazing by the goats may help to control insects, rodents, smells and littering to the extent that it is sufficient to lay a soil cover only once a week.

The incorporation of the goats in this way suggests how different approaches should be used in different situations to minimise disruption, pollution and cost, and to take advantage of existing practices, wherever possible. It may be found that it is not necessary to cover the wastes with soil each day because the wastes are covered with a layer of fresh waste every second day and this may be enough to control fly breeding, and because windblown paper and plastic should be caught by the netting or mesh barrier around the operational cell.

The tractor driver would also act as the site manager, directing traffic and controlling all operations on the site. The driver would be assisted by one labourer or watchman. A night watchman might also be necessary.

Readers are reminded that this system has not been fully tested, although the equipment proposed has been widely used for agricultural work. The authors would be very pleased to hear from anyone who would like to include a trial of this system in one of their projects.

A5.5 IMPLICATIONS OF DISPOSAL FOR WASTE COLLECTION AND TRANSPORT EQUIPMENT

A5.5.1 Journey time and costs

The time taken to carry collected solid waste to the disposal site is of crucial importance in the planning of a solid waste management system. (It should be noted that the time is more critical than the distance, because the time required for a journey to and from the disposal site determines the number of trips that a truck and its crew can make in one shift. Speed may be restricted and time

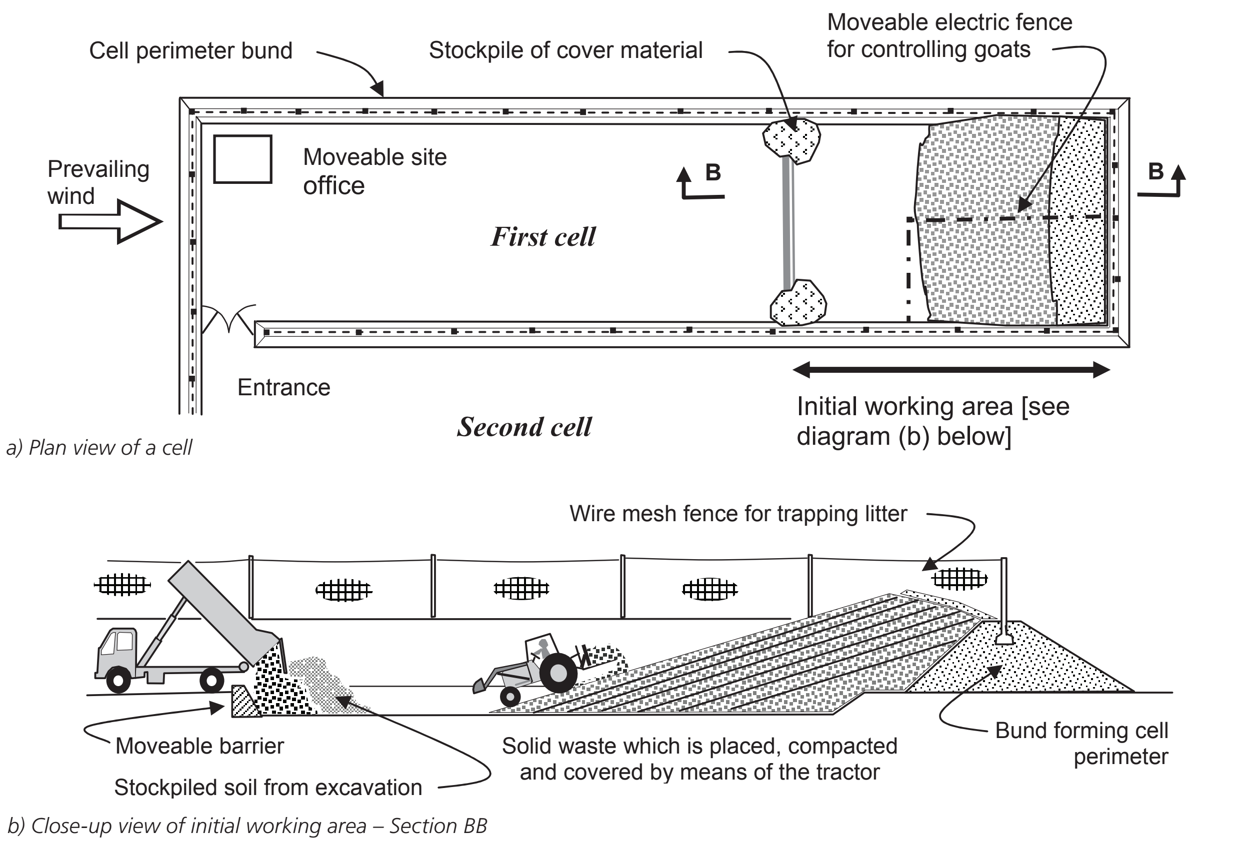


Figure A5.4 Proposal for constructing and operating a cell in a small landfill

extended by traffic congestion, poor road surfaces, sharp bends and steep gradients.) The journey time is a very important factor in determining the capacity and required top speed of the vehicles that are used for transporting waste. Often it is necessary to set up one or more transfer stations so that waste can be transferred from small or slow collection vehicles into larger and faster trucks. The costs and numbers of trips must be used to estimate – and later calculate – the costs of the transport operation, per ton of waste. These costs should be added to the costs of disposal (including any improvements to the access roads) to allow determination of the most economical integrated solution.

It is perhaps worth mentioning here that there is a trade-off between the costs of developing the access road and vehicle operation costs. Money spent on improving the access road may reduce vehicle operating costs by allowing faster speeds and therefore shorter journey times, and it may also reduce maintenance costs if the better road surface results in less damage to the springs and wheels of the vehicles.

An increase in the journey time, such as when one disposal site is closed and a more distant site is opened, can have a major effect on a solid waste collection system, because a longer journey time may require more vehicles or larger vehicles, or even the incorporation of a transfer station where previously none was necessary. There is a tendency for municipal authorities to choose a disposal site at a considerable distance from the city where land values are low. However, careful consideration should be given to the benefits (in terms of savings in total costs) of investing in a higher value site at a shorter distance from the city, having in mind that after closure and it can be re-incorporated into an expanding city.

A5.5.2 Driving on waste

Disposal not only influences the size and speed of the transportation used, but also has impacts on the design of the vehicles. Some vehicles have low ground clearances:

- Collection vehicles may have low ground clearances at the rear to lower the loading height so that the work of the loaders is easier. Some have low steps or small platforms for the loaders to ride on.
- Low entry crew cabs which are convenient for loaders to get into and out of may offer too little ground clearance at the front for driving over soft and irregular ground.
- Long, articulated trucks that can carry large quantities of waste may have equipment mounted under the long trailers such that it grounds on uneven terrain. The result could be damage to the equipment or the inability of the vehicle to operate on the site without being pushed or towed whenever it gets grounded (Photo 8.4).

Another design feature to consider when vehicles are driving over waste is avoiding wheelspin. For example, if a truck has a double rear axle, and only one axle is driven, the vehicle may get stuck regularly, especially when it in unloaded. This is because there is too little weight on the driven axle. The percentage of the total weight of the vehicle and trailer which is on the driving wheels determines its "traction" or ability to travel over soft or slippery surfaces. Articulated vehicles may suffer from loss of traction in the same way when the trailer is unloaded and there is little weight on the driven axle(s). Trailers pulled by agricultural tractors should be designed so that as much as one ton of the weight of the trailer is transferred to the large rear wheels of the tractor in order to ensure sufficient grip when driving on waste. The weight transfer is determined by the position of the trailer axle and the further back the axle the more weight is transferred.

Deposited solid waste, even after compaction, is relatively soft. Long vehicles carrying waste should be designed to empty without tipping the body, because when a long body is tipped to unload, the front of the body rises to a considerable height, and this overturning moment, together with the softness of the ground, causes a high risk that the vehicle will fall over onto its side, not only damaging the vehicle but threatening the life of anyone caught underneath the falling body [51]. Long vehicles should be fitted with hydraulic ejector plates that push the waste out or with moving floors.

A5.5.3 Unloading

Vehicles that transport waste should be able to unload quickly for at least three reasons:

- because manual unloading is unhygienic, requiring the labourers to have too much contact with the waste;
- because the time taken to drive to the disposal site, unload and return to the collection area should be as short as possible, to maximise the productivity of vehicle and manpower, and
- because the unloading area at a landfill site should be as small as possible; If many vehicles are unloading at the same time because the unloading process is slow, a large area is required.

51. *At one site where such articulated tippers were being used, it was necessary to put the bucket of a large 360° excavator into the body of the trailer in order to stop if from falling over.*

A6 LIST OF REFERENCES AND BIBLIOGRAPHY

A6.1 REFERENCES MENTIONED IN THE TEXT

ALI, M. and A. COTTON; 2001; *The Sweeping Business*; WEDC Loughborough University. UK <wedc@lboro.ac.uk>

AWORTWI, NICHOLAS; 2004; *Getting the fundamentals wrong: Woes of public-private partnerships in solid waste collection in three Ghanaian cities*; Public Administration and Development, 24, 213–224; www.interscience.wiley.com

BETTS, M., 1978; *Operational factors: a review of the main factors affecting solid waste management operations;* Waste Disposal and Resource Recovery, Proceedings of Regional Seminar on Solid Waste Management, Bangkok, 25–30 September 1978

BORNO, SALAH, 2000; *New solid waste collection system concept for developing countries*; Poster paper 17–4 presented at the CWG international workshop: *Planning for sustainable and integrated solid waste management*, held in Manila, the Philippines, September 2000. www.skat.ch [Available on the CD]

BUSVINE, JAMES R; 1982; *Control of Domestic Flies*; Ross Institute Bulletin No. 5, London School of Hygiene and Tropical Medicine, London, UK

CHINAMO, ELIAS.B.M.; 2003; *An overview of progress in Dar es Salaam*; paper 03 presented at CWG International Workshop *Solid waste collection that benefits the urban poor* ; held in Dar es Salaam., March 2003

COAD, ADRIAN; 1997; *Lessons from India in solid waste management*; WEDC, Loughborough University, UK; ISBN 0 906055 49 0 (Copies may still be available from Prof. Palnitkar via e-mail at <dir.rcues@aiilsg.org> or WEDC <WEDC@lboro.ac.uk>)

COAD, ADRIAN; 2000; *Planning for sustainable and integrated solid waste management*; report of CWG international workshop, Manila, the Philippines, September 2000; www.skat.ch [Editorial available on the CD]

COINTREAU, S.J.; 1980 Onitsha Water Supply Project – Solid Waste Management Component, report of the World Bank, Washington DC; January 1980

COINTREAU, S.J.; 1982; *Environmental Management of Urban Solid Wastes in Developing Countries*; Urban Development Technical Paper No. 5; World Bank, Washington DC.

COINTREAU-LEVINE, SANDRA, 2000; *Guidance Pack – Private sector participation in municipal solid waste management*; Skat Switzerland, www.skat.ch; ISBN 3–908001–90–0. This pack consists of five booklets and is a very useful introduction to the subject. It is on the CD included with the report (Coad, 2005) listed in Annex A6.2 and can be downloaded from http://rru.worldbank.org/Toolkits/SolidWasteManagement/

COOK, D.B. et al.; 1977; *Indian Appraisal of the Second Calcutta Urban Development Project*; Report No. 1662a-IN; World Bank, Washington DC.

DIAS, SONIA MARIA; 2006; *Waste and Citizenship Forums – achievements and limitations*, presented as Paper 11 at the CWG-WASH international workshop: "Solid waste, health and the Millennium Development Goals", Kolkata, India; February 2006 [Available on the CD]

EL-HAMOUZ, A.M.; 2007; *Logistical management and private sector involvement in reducing the cost of municipal solid waste collection service in the Tubas area of the West Bank*; Waste management [2007], doi:10.1016/j.wasman.2006.11.012; available on-line at www.sciencedirect.com

FLINTOFF, FRANK; 1976; *Management of Solid Wastes in Developing Countries*; World Health Organisation, South-East Asia Series No. 1, New Delhi

IMAM, A, et al.; 2007; *Solid waste management in Abuja, Nigeria*, Waste Management, doi:10.1016/j.wasman.2007.01.006. Available on-line at www.sciencedirect.com

LARDINOIS, INGE [ed.]; undated; *Solid waste micro and small enterprises and cooperatives in Latin-America*; www.gdrc.org/uem/waste/swm-waste.html

MEDINA, MARTIN; 2005; *Serving the unserved: Informal refuse collection in Mexico*; Waste Management Research 2005, 23, 390–7. See also paper 17 at CWG international workshop "Solid waste collection that benefits the urban poor"; Dar es Salaam, March 2003; www.skat.ch [Available on the CD]

Ngainayo, C.M.; 1986; *Disposal of Solid Wastes in Moshi and Arusha Towns, Tanzania*; Department of Civil Engineering, Tampere University of Technology, Finland

Phang Siew Nooi and Malcolm W Norris; 1996; *Performance of a local council in solid waste management: A study of supervision and control of human resources*; UMP-Asia Occasional Paper No.25.

Rahman, Shaikh Ferdausur; 2003; *Incorporating slum dwellers in solid waste collection programmes in Bangladesh*; presented as Paper 18 in the CWG international workshop "Solid waste collection that benefits the urban poor"; Dar es Salaam, Tanzania, March 2003. For more information visit www.skat.ch [Available on the CD]

Rouse, Jonathan R; 2006; *Seeking common ground for people: Livelihoods, governance and waste*; Habitat International 30 [2006] 741–753; www.elsevier.com/locate/habitatint

Scheu, Manfred and Adrian Coad; 1994; *Observations of solid waste management in Bombay*; WEDC, Loughborough University, UK; ISBN 0 906055 40 7

Scheu, Manfred, and Salah Borno, 2000; *Bridging the gap between public and private sectors*; paper presented at the CWG international workshop "Planning for sustainable and integrated solid waste management" Manila, Philippines, September 2000 [Available on the CD]

Scheu, Manfred; 2003; *Tailor-made collection system for high-density waste in Gaza*; Paper 42 presented at the CWG international workshop "Solid waste collection that benefits the urban poor"; Dar es Salaam, Tanzania, March 2003 [Available on the CD]

TVE.org; *Sweeping Changes – Bangladesh*; Report 1 [of 5]; Hands On – The Earth Report from TVE.org; www.handsontv.info

van de **Klundert**, A, A. Scheinberg, M. Muller, N. Dulac, L. Hoffman; 2001; *Integrated Sustainable Waste Management – A Set of Five Tools for Decision- makers*; WASTE – Advisers on urban environment and development, the Netherlands; www waste.nl

UNCHS (Habitat); 1988; *Development Planning for Peshawar – Solid Waste Management Project Preparation,* draft final report

A6.2 BIBLIOGRAPHY – SUGGESTIONS FOR FURTHER READING

A6.2.1 Comprehensive texts

Tchobanoglous, George, Hilary Theisen and Samuel A Vigil; 1993; *Integrated solid waste management: Engineering principles and management issues*; McGraw-Hill, ISBN 0 07 112865 4. This is a general text aimed at the North American market, so care should be taken not to accept conclusions that are relevant only to the USA.

Diaz, Luis F., George M Savage, Linda L Eggerth and Clarence G Golueke; 1996; *Solid waste management for economically developing countries*, ISWA, Copenhagen; ISBN 87–90402–01–4

A6.2.2 Sources related to specific chapters

Chapter 7 – Waste collection vehicles

- Carts and small vehicles

Rouse, Jonathan and Mansoor Ali; 2002; *Vehicles for people or people for vehicles – Issues in waste collection*; WEDC, Loughborough University, UK; ISBN 1 84380 012 8; available on-line at www.lboro.ac.uk/wedc/publications/vfp.htm. This book investigates the use and design of carts and small vehicles for waste collection, considering the technical, social and institutional aspects.

Hathway, Gordon; 1985; *Low-cost vehicles: options for moving people and goods*; Practical Action [formerly ITDG] UK; www.developmentbookshop.com; This book provides an illustrated guide to low-cost forms of transport. It is not only concerned with solid waste management, but has many applications in this field. It aims to inform decision-makers of the range of low-cost vehicles that are available.

Barwell, I and Gordon Hathway; 1986; *The design and manufacture of animal-drawn carts*; ISBN 0 94668 852 4; Practical Action [formerly ITDG] UK; www.development-bookshop.com; A manual on the design and manufacture of animal-drawn carts, based on existing experiences and suggesting improvements.

IT Publications; 1988; *The design and manufacture of low-cost motorized vehicles*; ISBN 1 85539 070 4; Practical Action [formerly ITDG] UK; www.developmentbookshop.com; For planners and manufacturers; detailed technical information on the design and manufacture of low-cost motor vehicles that can be produced locally.

Starkey, Paul, Emmanuel Mwenya and John Stares [eds.]; *Improving animal traction technology*; CTA, the Netherlands, ISBN 92–9081–127–7.

Dennis, R.A.; 1994; *Making wheels: A technical manual on wheel manufacture*; ITP, UK; ISBN 1–85339 141 7; www.developmentbookshop.com

Chapter 8 – Transport options

Cointreau, Sandra; 2005, *Solid waste transfer systems in developing countries*; It is based on a PowerPoint presentation and provides summary points and photographs that show performance data and designs for various transfer arrangements. Available at www.worldbank.org/urban/urbanforum2005/ulwpresentations/sw/cointreau.pdf

Chapter 11 – Institutional aspects

Private sector participation

Coad, Adrian, 2005; *Private sector involvement in solid waste management – Avoiding problems and building on successes*; GTZ Germany, www.gtz.de. This report is available as a small booklet or as the full report. Both versions include a CD with a wide range of additional information.

Ahmed, Shafiul Azam and Syed Mansoor Ali; 2006; *People as partners: Facilitating people's participation in public-private partnerships for solid waste management*; Habitat International 30 [2006] 781–796; www.elsevier.com/locate/habitatint

The informal sector

Ali, Mansoor; 2000; *The Sweeping Business: Developing entrepreneurial skills for the collection of solid waste*; WEDC, Loughborough University, UK; ISBN 0 906055 85 7; available on-line at www.lboro.ac.uk/wedc/publications. This book has been written for practitioners, municipal staff, non-government organizations and students interested in promoting micro-enterprises for the collection of solid waste. It provides a good understanding of the lives and situations of sweepers and primary waste collectors in the Indian subcontinent, and of the interface between the municipal system and the informal sector. It offers useful information on the setting up of small local enterprises.

Coad, Adrian; 2006; *Solid Waste, Health and the Millennium Development Goals*; report of the CWG international workshop at Kolkata, India, February 2006. The full papers are available on the CD provided with the report and can also be downloaded from www.cwgnet.net. Of particular relevance to the informal sector are papers #10 [Medina], #11 [Dias], #19 [Rouse], #33 [Chaturvedi], #34 Koehs, #35 [Spies & Wehenpohl], #56 [Scheinberg et al.] and #80 [Karawy].

Rouse, Jonathan and Mansoor Ali; 2000; *Waste pickers in Dhaka: Using the sustainable livelihoods approach; Key findings and field notes*; WEDC, Loughborough University, UK; ISBN 0 906055 84 9; available on-line at www.lboro.ac.uk/wedc/publications ; Waste pickers in Dhaka make their living by selling recyclable items collected from dumped waste. Most are children living on the streets or in slums where they have little access to infrastructure, a low status in society and an uncertain future. This book is based on a period of fieldwork in Dhaka which explored their livelihoods using the DFID Sustainable Livelihoods Approach

Wilson, David C, Costas Velis and Chris Cheeseman; 2006; Role of informal sector recycling in waste management in developing countries; Habitat International 30, (4) December 2006, 797–808. A useful summary of the situation of the informal sector, with emphasis on health aspects and possible measures for integrating the informal sector.

Annex A1 – Collecting data on waste collection operations

Sakura, Kunitoshi; 1990; *Improvement of solid waste management in developing countries*; Institute for International Co-operation, Japan International Co-operation Agency. Chapter 4 is about improving collection and section 4.3 is about time and motion studies [equivalent to work study].

Annex A4 – Recycling and treatment

Composting and recycling

Ali, Mansoor; 2004; *Sustainable composting*; WEDC, www.lboro.ac.uk Loughborough University, UK; This book comprises a series of case studies from around the world, each looking at how marketing contributed to a wide range of composting initiatives.

Rothenberger, S and C. Zurbrugg; 2006; *Decentralised Composing for Cities of Low- and Middle-income Countries. A User's Manual.* Sandec, Switzerland and Waste Concern, Bangladesh. This manual provides step-by-step guidelines on how to initiate a decentralised composting project in a developing country. It is written for communities and practitioners alike, including local authorities, private sector and NGO operators. Available online at www.sandec.ch

LIST OF TERMINOLOGY

A7

Term *Definition* Key references (section numbers)

appropriate *The word "appropriate" is used in its original, broader sense, and not in the sense often understood by the term "appropriate technology". In this book "appropriate" means well suited to the task to be performed, the local economic situation, and the expectations and attitudes of the local people, and able to perform in the local context in a way that is reliable, effective and cost-efficient. Sophisticated and automated technologies are appropriate in certain circumstances and simple technologies are appropriate in other conditions.*

articulated truck *An articulated truck is also known as a tractor and semi-trailer. It consists of a tractor unit which is like a short truck and a long trailer with one to three axles at the back.* 8.3

availability *The percentage of the time that a vehicle is in good condition and ready for service, or the number of vehicles of a particular type that are ready for service divided by the total number of these vehicles. The figures should be averages over a time period rather than based on data for one day.* 9.5

body *In the context of waste collection vehicles, the body is the load-carrying part of the vehicle that contains the waste. The manufacturer of specialist waste collection bodies is usually different from the manufacturer of the chassis.* 7.2

CBO *Community-based organisation – an association of people who live in the same area and work together to benefit the area where they live.*

chain *The solid waste management chain is the sequence of operations that begins with generation of the waste (when it is decided that an item is no longer wanted or considered to have value) until disposal. The links in this chain may include segregation, storage, collection, transfer, transport, processing and disposal.* 4.1

chassis *The basic vehicle on which the body can be fitted. The chassis comprises the motor and transmission, and wheels, together with the frame that holds them all together. The cab is not included. This is a French word and so is pronounced "shassy" and has the same form for both singular and plural.* 7.1.8

cleansing *This term covers the aspects of solid waste that are concerned with removing wastes from urban areas, so it refers to both solid waste collection and cleaning the streets.*

collection *In this publication, waste collection is considered to start with initial storage of the waste, because of its many and close links with collection, and include all stages of collection and transport of the waste, including any transfer of the waste from one means of collection or transport to the next. The collection stage ends when the waste is unloaded at a treatment plant or disposal site.*

compactor *This word is used in four ways.*

a) *A compactor truck has a body with a mechanism that packs solid waste tightly so that it fills the body. The volume of solid waste before it is loaded into the body is more than the volume into which it is packed because of the action of the loading mechanism that compresses or compacts the waste.*

b) *A compactor container is a container that has, at one end, a mechanism that fills the container with waste and compresses the waste to maximise the amount of waste that can be loaded. The container can be lifted onto the back of a truck.*

c) *A static compactor is used at transfer stations to load waste into containers so that the containers are full and contain the maximum amount of waste because the waste has been compressed or compacted.*

d) *A landfill compactor is a heavy machine with a large bulldozer blade and steel wheels that are fitted with projecting teeth. This type of machine is used to level and compact waste after it has been unloaded. Compacting the waste maximises the amount of waste that can be accommodated on a landfill site and results in other operational benefits.*

compost, composting *The conversion of the biodegradable organic matter in solid waste into a material which can be used by farmers and horticulturists for soil improvement and, to a lesser extent, fertilising crops. Co-composting is the addition of other materials such as sewage sludge to the composting material to increase the fertilising benefits.* A4.2.5

community containers *Also called communal containers, street containers or secondary storage. These are containers for municipal solid wastes that are provided by the waste collection agency such that each one is used by several households or businesses.* 5.3

consolidation *This refers to the reduction of the volume of a sample of solid waste as a result of natural (that is not mechanical) processes. The volume of the waste is reduced as paper and cardboard lose their strength as they become wet, as the result of gradual decomposition of biodegradable materials, and because of the downwards force exerted by overlying waste.* 3.2.2

construction & demolition debris *Waste derived from the construction or demolition of buildings including concrete, brick, stone, etc with some wood and steel reinforcing.* 3.1

coverage *"Service coverage" refers to the geographical extent of a waste collection service. For example, unplanned or squatter areas may not receive a waste collection service. Coverage can de defined as the proportion of an urban population that receives the service, expressed as a percentage of the total population.* 2.3.1

disposal *In this publication, disposal is defined as all actions concerned with placing waste and residues in their final resting place. Disposal in many countries generally means crude or open dumping, but this method of disposal is unsatisfactory because of the pollution of air, water and land that it causes. Satisfactory methods of disposal are known as sanitary landfilling.* A5

downtime *This is the time, usually measured in days, during which a vehicle or other piece of equipment cannot be used for its intended purpose because it requires maintenance or repair. If a vehicle is in serviceable condition but is not being used because it is not needed, this is not regarded as downtime. (See also availability)* 9.5

dump, dumping *Dumping of waste, often called "crude dumping" or "open dumping", is the unloading of waste on any available piece of ground, with no measures to minimise the environmental impact of this action. See disposal* A5.1

dustbin *A container for waste. In Britain a dustbin is a container with a lid, made of plastic or galvanised steel with a capacity of 60 to 80 litres. In India the term has a wider definition, and may refer to a masonry street container.* 5.2

economic life *The period over which a vehicle should be depreciated. It is the time after which the operating cost exceeds the operating cost of a new vehicle because of increased maintenance and downtime, decreased efficiency and excessive fuel costs.* 10.3.1

foliage *Vegetation from tree pruning, flower beds and grass cutting, from public parks and roadside trees as well as from private gardens. Fallen leaves may be included or regarded as street waste. Also known as green waste and garden waste* 3.1

GVW *Gross vehicle weight – the maximum legal weight for a loaded truck.* 7.2

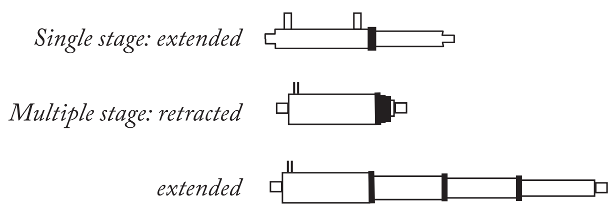
generator *A waste generator is a person or organisation which decides that an item is of no further use and therefore wishes that it is taken away. (The word "producer" is not used since this infers some type of industrial production process.)* 2.3.1

hazardous solid waste *Any waste which requires special handling or treatment during or before disposal because of its reactive, toxic, corrosive, inflammable or explosive nature. In many countries legislation defines which wastes are hazardous. Some items that may be found in household wastes are hazardous, but the larger sources are industries and healthcare facilities (such as hospitals and clinics).* 3.1

high-tipping *A mechanism that discharges waste at a height (generally) above 1.2 m. This allows waste to be transferred directly from the high-tipping vehicle to another vehicle or to a container, without touching the ground.* 8.2.1

hook lift *A vehicle that picks up containers by means of a hook on a hydraulically operated arm. The end of the container that is not picked up is fitted with rollers. Also known as arm roll". The roll-on-roll-off system is similar, but lifts the containers by means of a winch and cable.* 7.9.3

hydraulic cylinders *Hydraulic cylinders are used to push or pull, so that they can operate mechanisms such as binlifts, compaction mechanisms and the ejector plates that push waste out of a truck body.*



They are also referred to as rams.
(Note: A single action cylinder only has one hose connection at the rear end and so can only exert force to extend the ram. A double action cylinder has two connections – as shown for the single stage ram – so that it can pull as well as push. A multi stage cylinder only has one connection at the rear.) 7.7.1

incineration *The combustion of waste at high temperatures and in controlled conditions so that the volume of the resulting ash is as small as possible, and the resulting air and water pollution are minimised.* A4.3.1

informal *The "informal sector" refers to people who work outside organisations that are registered with government. Such people may work alone, with family groups or with small unregistered enterprises. They do not pay taxes or conform to safety and environmental legislation and may suffer harassment from officials or the police.* 11.3

integrated *This is a word which is commonly used in solid waste management. Sometimes it is used to indicate a particular approach to planning. Sometimes it is used to give the impression of a modern approach. In more general terms integrated solid waste management means an approach that considers all other parts of the solid waste management chain, involves all stakeholders in planning* *and reflects an awareness of all of the likely impacts of a decision.* 1.1

legal framework *The system of laws, regulations and enforcement mechanisms that defines the obligations, duties and rights of citizens.*

level of service *In the context of waste collection, "level of service" refers to the convenience and frequency of the service. For example, a daily collection service represents a higher level of service than a service which collects the waste once a week.* 4.3.1

loader *A manual labourer who is employed to pick up waste (loose or in a container) and load it onto or into a truck. (If a machine is being referred to it would be called a wheeled loader or a tracked loader.)* 7.1.6

monitoring *The regular collection, use and review of data that indicate inputs and outputs.* 9.3

municipal solid waste *Unwanted materials and items (that are not discharged from the premises in a pipe) which originate in homes, shops, offices, institutions and in streets and public places. This category may include solid wastes that are not more hazardous than domestic wastes and that originate in small industries and medical facilities.* 1.1

NGO *Non-governmental organisation An association of people who work together for a declared purpose but are administratively outside the government. Most countries have legislation that defines how an NGO can be established and funded.*

odometer *The indicator on a speedometer in a motor vehicle that shows the distance that the vehicle has covered. In some countries it is called a mileometer.* A2.3

organic *Widely used to mean biodegradable or putrescible when applied to solid waste. (In chemical terms, plastic is organic, but within the scope of solid waste management it is not included in the category of organic wastes.)* 3.1

payload *The payload is the weight of waste or other material which a vehicle can carry without exceeding the manufacturer's or legal maximum total weight. Payload = GVW minus the tare weight and minus the weight of the crew and fuel.* 7.2

picker *A person who removes materials with some economic value from mixed solid wastes. In most cases pickers are self-employed and are in the informal sector. Pickers collect recyclable material from the streets, from containers, from collection vehicles or from disposal sites. In some countries the word scavenger is used, but in others it is regarded as degrading.* 2.2.1

political will *The interests and intentions of local and national government decision-makers with respect to a particular issue. The degree of motivation and interest that they have to make changes in a particular aspect of their administration.*

public good *A term used by economists to indicate that the benefit of the service goes not only to those who pay a fee but to all. If my neighbour does not pay the waste management fee and his waste is not collected, I suffer if it is dumped in my neighbourhood. If his waste is collected without his paying the fee, he is benefiting from the fees paid by others. A private good, such as piped water, benefits only the individual who pays for it.* 10.4.1

recovery *Resource recovery includes any measure that gains some economic value from waste. It includes recycling energy recovery. Energy recovery is the generation of energy that is utilised for an economic purpose from the burning of the wastes themselves or of any solid, liquid or gaseous product that is derived from the waste. The French word valorisation has a similar meaning.* A4.1

recycling *In this publication, recycling means the returning to the economy of items or materials that someone else has discarded. The stages involved in recycling may include picking, transporting, trading, sorting, cleaning and processing. In some cases manufacturing may also be included. Reuse of items for the same purpose as that for which they were originally used (such as soft drink bottles) is also included.* A4.1

refuse *When pronounced so that the accent is on the first syllable, refuse means the same as municipal solid waste. The words refuse and waste are used interchangeably in this book.*

residual value *The resale value of a vehicle or other item after it has reached the end of the economic life.* 10.3.1

sanitary landfill *A sanitary landfill is a facility that has been prepared so that it is possible to dispose of solid waste in a way that causes minimal pollution of air or water, and that uses the land in the most economical way. When all operations at the site cease, the site should be returned to a condition that is similar or better than the surroundings. Sanitary landfilling is the operation of the facility in such a way that these objectives are realised. Unfortunately some sanitary landfills are not operated correctly and soon become similar to open dumps. (See "disposal")* A.5.1

segregation *The storing of different categories of waste in different containers and subsequent handling so that they are never mixed.* 2.2.1

separation *Dividing a body of waste that has two or more components mixed together into two or more piles or streams that are more homogeneous. For example, mixed domestic refuse can be separated into recyclable materials (as one stream) and materials that have no potential for recycling (as another).*

service, servicing *The word "service" can have two meanings in the context of waste collection. When used as "collection service", "out-of-service costs" or "service level" it refers to an activity that is performed for the benefit of the public. However, the word "service" is used in the motor industry to describe the regular work done in a garage such as oiling, greasing, changing filters and adjusting brakes. Maintenance also includes repairs. Vehicles are supplied with service books and service sheets and the work is often done by a service man as opposed to a repair mechanic. In this publication the word "service" is generally used for the first meaning, and "servicing" is used in the context of vehicle maintenance.* A2

shadow costing *A method used to assess the costs to the national economy of wages, of purchasing and using a particular vehicle or piece of equipment, or of providing a service, rather than the actual costs to the local authority or other operators. It makes allowance for import duties, value added taxes, and other revenues returning to the national exchequer including direct and indirect taxes paid by the workers on their wages and purchases.* 10.6

solid waste *There are many complex legal definitions of solid waste. For the purposes of this booklet, solid waste is defined as any item or material that is discarded by its owner and that is not discharged in gaseous form to the atmosphere, to a pit latrine or via a pipe or channel. Solid waste may include gases and liquids in containers.*

solid waste management *Solid waste management encompasses all the activities undertaken or required to minimise the impact of solid waste on health, the environment, the economy and aesthetics.*

stage *The solid waste management chain is considered as a succession of stages that are the links in the chain. Generation, collection, recycling and disposal are therefore all stages.*

stakeholder *A stakeholder in an issue is anyone who has an interest in the issue or may be affected by it. For example, informal sector rag pickers, residents and vehicle mechanics are all stakeholders in a waste collection service.* 1.1

standardisation *This refers to the deliberate use of only one design, model or type of waste container or vehicle in order to ensure compatibility between containers and lifting mechanisms or to simplify maintenance and the stocking of spare parts.* 5.4

supervision *Observing the activities of employees with the aim of maintaining a certain standard of working. (This is not to be confused with monitoring [above].)* 12.8

tare *The empty weight of the vehicle before it is loaded. (Also known as kerb weight).* 7.2

tracked loader *An earthmoving machine that can dig and pick up loose material with a hydraulically operated bucket at the front, and that runs on tracks rather than on wheels* A5.3

transfer *Transfer, as an operation, is the moving of waste from a primary collection vehicle to a larger and/or faster vehicle in order to save transport costs. This operation often takes place at a transfer station. The larger or faster secondary vehicle is sometimes referred to as a transfer truck, though usually in this book the term secondary transport truck is used, to avoid confusion.* 8

wheeled loader *A four-wheeled machine fitted with a large bucket which can pick up loose material from the ground and load it into trucks. (See Photo 8.1)*

work study *Sometimes referred to as time and motion study. The study of the labour operating any vehicle or equipment. It includes the "ergonomics" of the operations.* A1

LIST OF FIGURES, PICTURES AND TABLES

HS/139/10E
ISBN: (Volume) 978-92-1-132254-5

United Nations Human Settlements Programme
P.O. Box 30030, GPO Nairobi, 00100, Kenya
Telephone: +254 20 762 3120
Fax: +254 20 762 3477
infohabitat@unhabitat.org
www.unhabitat.org

Printed in Malta 2010

UN HABITAT