Lecture 3

Waste Collection, Storage and Transport

STRUCTURE

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OVERVIEW

For the final disposal of the wastes generated (see Unit 2), it is imperative that we put in place an effective waste collection system, which we described in Unit 1 (see (iii) of Subsection 1.2.1). In Unit 3, we will build on this description and discuss in detail the various aspects of collection system. Accordingly, we will first explain the components of waste collection such as storage, collection crew, route, transfer station, etc. We will then discuss each of these components. We will also discuss the design, operation and implementation of waste collection
systems. We will close the Unit with a case study highlighting waste storage, collection and transport.

**LEARNING OBJECTIVES**

After completing this Unit, you should be able to:

- discuss the various components of a waste collection system;
- explain the characteristics of waste containers relative to their use;
- state the purpose of a transfer station;
- evaluate how a collection system is planned and implemented;
- collect and maintain the required data for record keeping and inventory control;
- design and implement a collection system.

**3.1 COLLECTION COMPONENTS**

As described in Subsection 1.2.1, Unit 1, waste collection does not mean merely the gathering of wastes, and the process includes, as well, the transporting of wastes to transfer stations and/or disposal sites. To elaborate, the factors that influence the waste collection system include the following (EPA, 1989 and Ali, et al., 1999):

(i) **Collection points:** These affect such collection system components as crew size and storage, which ultimately control the cost of collection. Note that the collection points depend on locality and may be residential, commercial or industrial.

(ii) **Collection frequency:** Climatic conditions and requirements of a locality as well as containers and costs determine the collection frequency. In hot and humid climates, for example, solid wastes must be collected at least twice a week, as the decomposing solid wastes produce bad odour and leachate.
And, as residential wastes usually contain food wastes and other putrescible (rotting) material, frequent collection is desirable for health and aesthetic reasons. Besides climates, the quality of solid waste containers on site also determines the collection frequency. For instance, while sealed or closed containers allow collection frequency up to three days, open and unsealed containers may require daily collection. Collection efficiency largely depends on the demography of the area (such as income groups, community, etc.), where collection takes place. While deciding collection frequency, therefore, you must consider the following:

- cost, e.g., optimal collection frequency reduces the cost as it involves fewer trucks, employees and reduction in total route distance;
- storage space, e.g., less frequent collection may require more storage space in the locality;
- sanitation, e.g., frequent collection reduces concerns about health, safety and nuisance associated with stored refuse.

(iii) **Storage containers** (see also Subsection 3.2.1): Proper container selection can save collection energy, increase the speed of collection and reduce crew size. Most importantly, containers should be functional for the amount and type of materials and collection vehicles used. Containers should also be durable, easy to handle, and economical, as well as resistant to corrosion, weather and animals. In residential areas, where refuse is collected manually, standardised metal or plastic containers are typically required for waste storage. When mechanised collection systems are used, containers are specifically designed to fit the truck-mounted loading mechanisms. While evaluating residential waste containers, consider the following:

- efficiency, i.e., the containers should help maximise the overall collection efficiency.
- convenience, i.e., the containers must be easily manageable both for residents and collection crew.
- compatibility, i.e., the containers must be compatible with collection equipment.
- public health and safety, i.e., the containers should be securely covered and stored.
- ownership, i.e., the municipal ownership must guarantee compatibility with collection equipment.

(iv) **Collection crew** (see also Subsection 3.3.1): The optimum crew size for a community depends on labour and equipment costs, collection methods and route characteristics. The size of the collection crew also depends on the size and type of collection vehicle used, space between the houses, waste generation rate and collection frequency. For example, increase in waste generation rate and quantity of wastes collected per stop due to less frequent collection result in a bigger crew size. Note also that the collection vehicle could be a motorised vehicle, a pushcart or a trailer towed by a suitable prime mover (tractor, etc.). It is possible to adjust the ratio of collectors to collection vehicles such that the crew idle time is minimised. However, it is not easy to implement this measure, as it may result in an overlap in the crew collection and truck idle time. An effective collection crew size and proper workforce management can influence the productivity of the collection system. The crew size, in essence, can have a great effect on overall collection costs. However, with increase in collection costs, the trend in recent years is towards:

- decrease in the frequency of collection;
- increase in the dependence on residents to sort waste materials;
- increase in the degree of automation used in collection.

This trend has, in fact, contributed to smaller crews in municipalities.

(v) **Collection route** (see also Subsection 3.3.2): The collection programme must consider the route that is efficient for collection. An efficient routing of
collection vehicles helps decrease costs by reducing the labour expended for collection. Proper planning of collection route also helps conserve energy and minimise working hours and vehicle fuel consumption. It is necessary therefore to develop detailed route configurations and collection schedules for the selected collection system. The size of each route, however, depends on the amount of waste collected per stop, distance between stops, loading time and traffic conditions. Barriers, such as railroad, embankments, rivers and roads with heavy traffic, can be considered to divide route territories. Routing (network) analyses and planning can:

- increase the likelihood of all streets being serviced equally and consistently;
- help supervisors locate or track crews quickly;
- provide optimal routes that can be tested against driver judgement and experience.

(vi) **Transfer station** (see also Section 3.4): A transfer station is an intermediate station between final disposal option and collection point in order to increase the efficiency of the system, as collection vehicles and crew remain closer to routes. If the disposal site is far from the collection area, it is justifiable to have a transfer station, where smaller collection vehicles transfer their loads to larger vehicles, which then haul the waste long distances. In some instances, the transfer station serves as a pre-processing point, where wastes are dewatered, scooped or compressed. A centralised sorting and recovery of recyclable materials are also carried out at transfer stations (EPA, 1989). The unit cost of hauling solid wastes from a collection area to a transfer station and then to a disposal site decreases, as the size of the collection vehicle increases. This is due to various reasons such as the following:

- labour costs remain constant;
- the ratio of payload to vehicle load increases with vehicle size;
the waiting time, unloading time, idle time at traffic lights and driver rest period are constant, regardless of the collection vehicle size.

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LEARNING ACTIVITY 3.1

Find the current waste collection practice in your locality and state its role in waste management.

**Note:**

a) Write your answer in the space given below.

b) Check your answer with the one given at the end of this Unit.

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Note that waste collection often proves to be the most costly component of any waste management system. However, with a proper collection system design and management, we can significantly reduce the costs. Consider the following criteria to evaluate, and make decisions about, collection systems:
Efficiency: Do the services help minimise the cost per household?

Effectiveness: Do the services satisfy the community needs?

Equity: Do the services address equally the concerns of all social and demographic groups?

Reliability: Do the services ensure consistency?

Safety and environmental impact: Do the services ensure safety of workers, public health and protection of the environment?

Note also that various management arrangements, ranging from municipal services to franchised services and under various forms of contracts are, typically, in vogue for waste collection. One of the critical decisions to be made at the planning stage, therefore, is as to who – the public or private agencies – operates the collection system, though the final decision depends on the existing conditions and options for the local decision-makers (EPA, 1989).

3.2 STORAGE: CONTAINERS/COLLECTION VEHICLES

As mentioned in Unit 1, waste storage is an important component of a waste management system. Waste storage encompasses proper containers to store wastes and efficient transport of wastes without any spillage to transfer stations/disposal sites. We will analyse these two aspects of waste storage in Subsections 3.2.1 and 3.2.2.

3.2.1 Containers/storage bins

The design of an efficient waste collection system requires careful consideration of the type, size and location of containers at the point of generation for storage of wastes until they are collected. While single-family households generally use small containers, residential units, commercial units, institutions and industries require large containers. Smaller containers are usually handled manually.
whereas the larger, heavier ones require mechanical handling. The containers may fall under either of the following two categories:

(i) Stationary containers: These are used for contents to be transferred to collection vehicles at the site of storage.

(ii) Hauled containers: These are used for contents to be directly transferred to a processing plant, transfer station or disposal site for emptying before being returned to the storage site.

The desirable characteristics of a well-designed container are low cost, size, weight, shape, resistance to corrosion, water tightness, strength and durability (Phelps, et al., 1995). For example, a container for manual handling by one person should not weigh more than 20 kg, lest it may lead to occupational health hazards such as muscular strain, etc. Containers that weigh more than 20 kg, when full, require two or more crew members to manually load and unload the wastes, and which result in low collection efficiency.

Containers should not have rough or sharp edges, and preferably have a handle and a wheel to facilitate mobility. They should be covered to prevent rainwater from entering (which increases the weight and rate of decomposition of organic materials) into the solid wastes. The container body must be strong enough to resist and discourage stray animals and scavengers from ripping it as well as withstand rough handling by the collection crew and mechanical loading equipment. Containers should be provided with a lifting bar, compatible with the hoisting mechanism of the vehicle. The material used should be light, recyclable, easily moulded and the surface must be smooth and resistant to corrosion. On the one hand, steel and ferrous containers are heavy and subject to corrosion; the rust peels off exposing sharp edges, which could be hazardous to the collection crew. On the other, wooden containers (e.g., bamboo, rattan and wooden baskets) readily absorb and retain moisture and their surfaces are generally rough, irregular and difficult to clean.
**Communal containers**

Generally, the containers used for waste storage are communal/public containers. Figure 3.1 below shows a typical communal container, which a compactor collection vehicle (see Figure 3.5) can lift and empty mechanically:

![Typical Communal Container](image)

The use of communal containers is largely dependent on local culture, tradition and attitudes towards waste. Communal containers may be fixed on the ground (stationary) or movable (hauled). Movable containers are provided with hoists and tails compatible with lifting mechanism of collection vehicles and such containers have capacities of 1 – 4 m³. The waste management authority must monitor, maintain and upgrade the communal containers. Note that in residential and commercial areas in India, the communal containers are often made of concrete.
In areas with very high waste generation rates, i.e., rates exceeding two truckloads daily, such as wet markets, large commercial centres and large business establishments, roll-on-roll or hoisted communal containers with capacities of 12 – 20 m$^3$ and a strong superstructure with wheels are used. Normally, the collection vehicle keeps an empty container as a replacement before it hauls the filled container. When a truck is used as a collection vehicle, the use of communal containers may be appropriate.

It is advisable to place the containers 100 – 200 m apart for economic reasons. The communal containers are usually staggered such that the effective distance of 100 m is maintained as shown in Figure 3.2:

**Figure 3.2**
Location of Communal Container
This means that the farthest distance the householder will have to walk is 50 meters. However, in narrow streets with low traffic, where the house owner can readily cross the street, a longer distance is advisable. If the collection vehicle has to stop frequently, say, at every 50 m or so, fuel consumption increases, and this must be avoided.

**Disadvantages**
The major disadvantage of communal containers is the potential lack of maintenance and upgrading. The residuals and scattered solid wastes emit foul odours, which discourage residents from using the containers properly. In addition, if fixed containers are built below the vehicle level, the collection crew may be held responsible for sweeping and loading the solid wastes into transfer containers before being loaded into the collection vehicle. Sweeping and cleaning the communal containers of residuals obviously impinge on the time of the crew members and take a longer time than if the wastes are placed in smaller containers. As fixed communal containers have higher rates of failure, their use is not advisable.
To overcome the problem of maintaining communal containers, individual residents should maintain their own containers and locate them in designated areas. The communal area must have water and drains to facilitate the cleaning of the containers. This practice has the advantage of reducing the number of collection stops and at the same time maintaining the householder's responsibility for cleaning them. The residents must also be properly educated on the importance of good housekeeping as the containers in the communal area are subject to vandalism. In the main, if communal containers are to be successful, the design of the containers, loading and unloading areas, and collection vehicle accessories should be co-ordinated.

3.2.2 Collection vehicles

Almost all collections are based on collector and collection crew, which move through the collection service area with a vehicle for collecting the waste material. The collection vehicle selected must be appropriate to the terrain, type and density of waste generation points, the way it travels and type and kind of material (UNEP, 1996). It also depends upon strength, stature and capability of the crew that will work with it. The collection vehicle may be small and simple (e.g., two-wheeled cart pulled by an individual) or large, complex and energy intensive (e.g., rear loading compactor truck). The most commonly used collection vehicle is the dump truck fitted with a hydraulic lifting mechanism. A description of some vehicle types follows:

(i) Small-scale collection and muscle-powered vehicles: These are common vehicles used for waste collection in many countries and are generally used in rural hilly areas. As Figure 3.3 illustrates, these can be small rickshaws, carts or wagons pulled by people or animals, and are less expensive, easier to build and maintain compared to other vehicles:
They are suitable for densely populated areas with narrow lanes, and squatter settlements, where there is relatively low volume of waste generated. Some drawbacks of these collection vehicles include limited travel range of the vehicles and weather exposure that affect humans and animals.

(ii) **Non-compactor trucks:** Non-compactor trucks are efficient and cost effective in small cities and in areas where wastes tend to be very dense and have little potential for compaction. Figure 3.4 illustrates a non-compactor truck:
When these trucks are used for waste collection, they need a dumping system to easily discharge the waste. It is generally required to cover the trucks in order to prevent residue flying off or rain soaking the wastes. Trucks with capacities of 10 – 12 m³ are effective, if the distance between the disposal site and the collection area is less than 15 km. If the distance is longer, a potential transfer station closer than 10 km from the collection area is required. Non-compactor trucks are generally used, when labour cost is high. Controlling and operating cost is a deciding factor, when collection routes are long and relatively sparsely populated.

(iii) **Compactor truck**: Compaction vehicles are more common these days, generally having capacities of 12 – 15 m³ due to limitations imposed by narrow roads. Although the capacity of a compaction vehicle, illustrated in Figure 3.4, is similar to that of a dump truck, the weight of solid wastes collected per trip is 2 to 2.5 times larger since the wastes are hydraulically compacted:
Figure 3.5
Compactor Truck

The success of waste management depends on the level of segregation at source. One of the examples for best collection method is illustrated in the figure below.

A compactor truck allows waste containers to be emptied into the vehicle from the rear, front or sides and inhibits vectors (of disease) from reaching the waste during collection and transport. It works poorly when waste
stream is very dense, wet, collected materials are gritty or abrasive, or when the roads are dusty. The advantages of the compactor collection vehicle include the following:

- containers are uniform, large, covered and relatively visually inoffensive;
- waste is set out in containers so that the crew can pick them up quickly;
- health risk to the collectors and odour on the streets are minimised;
- waste is relatively inaccessible to the waste pickers.

LEARNING ACTIVITY 3.2

What are the types of containers and collection vehicles in use in your locality?

Note:
a) Write your answer in the space given below.
b) Check your answer with the one given at the end of this Unit.
3.3 COLLECTION OPERATION

In Section 3.2, we introduced you to different types of containers and collection vehicles. We now discuss the movement of collection crew in terms of workforce efficiency and collection routes.

3.3.1 Movement of collection crew

In cultures such as India, Bangladesh, etc., solid waste collection is assigned to the lowest social group. More often, the collection crew member accepts the job as a temporary position or stopgap arrangement, while looking for other jobs that are considered more respectable.

Apart from this cultural problem, the attitude of some SWM authorities affects collection operation. For example, some authorities still think that the collection of solid waste is mechanical, and therefore, the collection crew does not need any training to acquire special skills. As a result, when a new waste collector starts working, he or she is sent to the field without firm instruction concerning his or her duties, responsibilities and required skills. For an effective collection operation, the collection team must properly be trained. The collection crew and the driver of the collection vehicle must, for example, work as a team, and this is important to maintain the team morale and a sense of social responsibility among these workers.

You must also note that the movement of collection crew, container location and vehicle stopping point affect collection system costs. Figure 3.6 highlights the distance the collection crew will have to walk, if it were to serve the farthest point first or serve the point closest to the vehicle:
The difference may be one or two minutes per collection stop, but it matters with the number of stops the crew will take in a working shift. Multiplying the minutes by the total number of crew working and labour cost depicts the amount of labour hours lost in terms of monetary value.

Generally, familiarity of the crew with the collection area improves efficiency. For example, the driver becomes familiar with the traffic jams, potholes and other obstructions that he or she must avoid. The crew is aware of the location of the containers and the vehicle stops. It is, therefore, important to assign each crew specific areas of responsibility. Working together also establishes an understanding of the strong and weak points of the team members and efficient work sequences. The collection operation must also observe a strict time schedule. Testing of new routes, new gadgets and vehicles is best carried out first in the laboratory and later in a pilot area. Testing of a new sequence using the whole service area could result in disorder and breakdown of the solid waste collection system. Studies show that it takes two hours to recover for every hour of a failed system.
**Motion time measurement (MTM) technique**

Motion time measurement (MTM) studies are now an integral part of the standard procedure in the development of solid waste collection systems. MTM is a technique to observe and estimate the movement of the collection crew with the help of stopwatches. The results thus gathered are tabulated as shown in Table 3.1 to determine the best sequence of activities that workers must follow in order to complete a repetitive task in the shortest possible time:

**Table 3.1**  
MTM Study: Determination of Time, Distance and Number on Containers in Collection Route

<table>
<thead>
<tr>
<th></th>
<th>Time</th>
<th>Odometer (Km)</th>
<th>Number of Containers</th>
<th>Collection time (Minute Second)</th>
<th>Trip time to next Station</th>
</tr>
</thead>
<tbody>
<tr>
<td>Garage</td>
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<tr>
<td>1 Station</td>
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<td>Last Station</td>
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<tr>
<td>Disposal Site</td>
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<td>Total</td>
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*Source: Phelps, et al., 1995*

MTM also helps in deciding the best combination of equipment to maintain a desired level of output, reduce health problems related to the repetitive work sequence and predict the effects of changes in materials handled. Sophisticated MTM studies involve hidden or open video cameras at different collection stops to record, replay and study the operation sequence of the collection crew. If the crew is conscious of being observed, they tend to work faster and reduce time wastage in unauthorised salvaging and other non-scheduled activities. Once the crew is familiar with the person(s) observing them,
it begins to perform more credibly. In studies involving video cameras, therefore, the first two or three hours of observation are often neglected.

### 3.3.2 Collection vehicle routing

Efficient routing and re-routing of solid waste collection vehicles can help decrease costs by reducing the labour expended for collection. Routing procedures usually consist of the following two separate components:

**Macro-routing:** Macro-routing, also referred to as route-balancing, consists of dividing the total collection area into routes, sized in such a way as to represent a day’s collection for each crew. The size of each route depends on the amount of waste collected per stop, distance between stops, loading time and traffic conditions. Barriers, such as railroad embankments, rivers and roads with heavy competing traffic, can be used to divide route territories. As much as possible, the size and shape of route areas should be balanced within the limits imposed by such barriers.

**Micro-routing:** Using the results of the macro-routing analysis, micro-routing can define the specific path that each crew and collection vehicle will take each collection day. Results of micro-routing analyses can then be used to readjust macro-routing decisions. Micro-routing analyses should also include input and review from experienced collection drivers.

**Districting** is the other method for collection route design. For larger areas it is not possible for one institution to handle it then the best way is to subdivide the area and MSW collection districting plan can be made. This routing will be successful only when road network integrity is good and the regional proximity has been generated.

The heuristic (i.e., trial and error) route development process is a relatively simple manual approach that applies specific routing patterns to block configurations. The map should show collection, service garage locations, disposal or transfer sites, one-way streets, natural barriers and areas of heavy
traffic flow. Routes should then be traced onto the tracing paper using the following rules:

- Routes should not be fragmented or overlapping. Each route should be compact, consisting of street segments clustered in the same geographical area.
- Total collection plus hauling time should be reasonably constant for each route in the community.
- The collection route should be started as close to the garage or motor pool as possible, taking into account heavily travelled and one-way streets.
- Heavily travelled streets should not be visited during rush hours.
- In the case of one-way streets, it is best to start the route near the upper end of the street, working down it through the looping process.
- Services on dead-end streets can be considered as services on the street segment that they intersect, since they can only be collected by passing down that street segment. To keep right turns at a minimum, (in countries where driving is left-oriented) collection from the dead-end streets is done when they are to the left of the truck. They must be collected by walking down, reversing the vehicle or taking a U-turn.
- Waste on a steep hill should be collected, when practical, on both sides of the street while vehicle is moving downhill. This facilitates safe, easy and fast collection. It also lessens wear of vehicle and conserves gas and oil.
- Higher elevations should be at the start of the route.
- For collection from one side of the street at a time, it is generally best to route with many anti-clockwise turns around blocks.
- For collection from both sides of the street at the same time, it is generally best to route with long, straight paths across the grid before looping anti-clockwise.
- For certain block configurations within the route, specific routing patterns should be applied. (Adapted from American Public Works Association, 1975.)
Based on the above rules, Figure 3.7 below illustrates a typical collection vehicle routing:

![Figure 3.7 Collection Vehicle Route](image-url)
Before we proceed any further, let us complete Learning Activity 3.3.

LEARNING ACTIVITY 3.3

State the rules that we need to keep in mind, while designing a collection route.

Note:

a) Write your answer in the space given below.

b) Check your answer with the one given at the end of this Unit.
3.4 TRANSFER STATION

As mentioned earlier in Section 3.1, transfer station is a centralised facility, where waste is unloaded from smaller collection vehicles and re-loaded into large vehicles for transport to a disposal or processing site. This transfer of waste is frequently accompanied by removal, separation or handling of waste. In areas, where wastes are not already dense, they may be compacted at a transfer station. The technical limitations of smaller collection vehicles and the low hauling cost of solid waste, using larger vehicles, make a transfer station viable. Also, the use of transfer station proves reasonable, when there is a need for vehicles servicing a collection route to travel shorter distances, unload and return quickly to their primary task of collecting the waste.

Limitations in hauling solid wastes are the main factors to be considered, while evaluating the use of transfer stations. These include the additional capital costs of purchasing trailers, building transfer stations and the extra time, labour and energy required for transferring wastes from collection truck to transfer trailer.

Consider also the following factors that affect the selection of a transfer station:

- Types of waste received.
Processes required in recovering material from wastes.

Required capacity and amount of waste storage desired.

Types of collection vehicles using the facility.

Types of transfer vehicles that can be accommodated at the disposal facilities.

Site topography and access.

The main problem in the establishment of a transfer station, however, is securing a suitable site. Stored solid wastes and recyclable materials, if not properly handled, will attract flies and other insect vectors. Odours from the transferred solid wastes will also be a nuisance, if not properly controlled. In addition, the traffic and noise due to small and large collection vehicles, collectors, drivers, etc., invite the resentment of the communities living in the vicinity of transfer stations (EPA, 1995).

3.4.1 Types

Depending on the size, transfer stations can be either of the following two types:

(i) Small to medium transfer stations: These are direct-discharge stations that provide no intermediate waste storage area. The capacities are generally small (less than 100 tonnes/day) and medium (100 to 500 tonnes/day). Depending on weather, site aesthetics and environmental concerns, transfer operations of this size may be located either indoor or outdoor. More complex small transfer stations are usually attended during hours of operation and may include some simple waste and materials processing facilities. For example, it includes a recyclable material separation and processing centre. The required overall station capacity (i.e., the number and size of containers) depends on the size and population density of the area served and the frequency of collection.
(ii) **Large transfer stations:** These are designed for heavy commercial use by private and municipal collection vehicles. The typical operational procedure for a larger station is as follows:

- when collection vehicles arrive at the site, they are checked in for billing, weighed and directed to the appropriate dumping area;
- collection vehicles travel to the dumping area and empty the wastes into a waiting trailer, a pit or a platform;
- after unloading, the collection vehicle leaves the site, and there is no need to weigh the departing vehicle, if its weight (empty) is known;
- Transfer vehicles are weighed either during or after loading. If weighed during loading, trailers can be more consistently loaded to just under maximum legal weights and this maximises payloads and minimises weight violations.

**Designs for larger transfer operations**

Several different designs for larger transfer operations are common, depending on the transfer distance and vehicle type. Most designs, however, fall into one of the following three categories:

(i) **Direct-discharge non-compaction station:** In these stations, waste is dumped directly from collection vehicle into waiting transfer trailers and is generally designed with two main operating floors. In the transfer operation, wastes are dumped directly from collection vehicles (on the top floor) through a hopper and into open top trailers on the lower floor. The trailers are often positioned on scales so that dumping can be stopped when the maximum payload is reached. A stationary crane with a bucket is often used to distribute the waste in the trailer. After loading, a cover or tarpaulin is placed over the trailer top. However, some provision for waste storage during peak time or system interruptions should be developed. Because of the use of little hydraulic equipment, a shutdown is unlikely and this station minimises handling of waste.
(ii) **Platform/pit non-compaction station:** In this arrangement, the collection vehicles dump their wastes onto a platform or into a pit using waste handling equipment, where wastes can be temporarily stored, and if desired, picked through for recyclables or unacceptable materials. The waste is then pushed into open-top trailers, usually by front-end loaders. Like direct discharge stations, platform stations have two levels. If a pit is used, however, the station has three levels. A major advantage of these stations is that they provide temporary storage, which allows peak inflow of wastes to be levelled out over a longer period. Construction costs for this type of facility are usually higher because of the increased floor space. This station provides convenient and efficient storage area and due to simplicity of operation and equipment, the potential for station shutdown is less.

(iii) **Compaction station:** In this type of station, the mechanical equipment is used to increase the density of wastes before they are transferred. The most common type of compaction station uses a hydraulically powered compactor to compress wastes. Wastes are fed into the compactor through a chute, either directly from collection trucks or after intermediate use of a pit. The hydraulic ram of the compactor pushes waste into the transfer trailer, which is usually mechanically linked to the compactor (EPA, 1995). Compaction stations are used when:

- wastes must be baled for shipment;
- open-top trailers cannot be used because of size restrictions;
- site topography or layout does not accommodate a multi-level building.

The main disadvantage of a compaction facility is that the facility's ability to process wastes is directly dependent on the operativeness of the compactor. Selection of a quality compactor, regular maintenance of the equipment, easy availability of spare parts and prompt availability of the service personnel are essential for the station’s reliable operation.
3.4.2 Capacity

A transfer station should have enough capacity to manage and handle the wastes at the facility throughout its operating life. While selecting the design capacity of a transfer station, we must, therefore, consider trade-offs between the capital costs associated with the station and equipment and the operational costs. Designers should also plan adequate space for waste storage and, if necessary, waste processing. Transfer stations are usually designed to have 1.5 – 2 days of storage capacity. The collection vehicle unloading area is usually the waste storage area and sometimes a waste sorting area. When planning the unloading area, designers should allow adequate space for vehicle and equipment manoeuvring. To minimise the space required, the facility should be designed such that the collection vehicle backs into the unloading position. Adequate space should also be available for offices, employee facilities, and other facility-related activities (EPA, 1995). Factors that should be considered in determining the appropriate capacity of a transfer facility include:

- capacity of collection vehicles using the facility;
- desired number of days of storage space on tipping floor;
- time required to unload collection vehicles;
- number of vehicles that will use the station and their expected days and hours of arrival;
- waste sorting or processing to be accomplished at the facility;
- transfer trailer capacity;
- hours of station operation;
- availability of transfer trailers waiting for loading;
- time required, if necessary, to attach and disconnect trailers from tractors or compactors.

Transfer station capacity can be determined using the following formulae:
(i) **Pit stations:** Based on the rate at which wastes can be unloaded from collection vehicles:

\[
C = P_c \times (L/W) \times (60 \times H_w/T_c) \times F
\]

Based on rate at which transfer trailers are loaded:

\[
C = (P_t \times N \times 60 \times H_t)/(T_t + B)
\]

(ii) **Direct dump stations:**

\[
C = (N_n \times P_t \times F \times 60 \times H_w)/\left[(P_t/P_c) \times (W/Ln)\right] \times T_c + B
\]

(iii) **Hopper compaction stations:**

\[
C = (N_n \times P_t \times F \times 60 \times H_w)/\left[(P_t/P_c) \times T_c\right] + B
\]

(iv) **Push pit compaction station:**

\[
C = (N_p \times P_t \times F \times 60 \times H_w)/\left[(P_t/P_c) \times W/L_p \times T_c\right] + B
\]

Where:

- \(C\) = Station capacity (tonnes/day);
- \(P_c\) = Collection vehicle payload (tonnes);
- \(L\) = Total length of dumping space (feet);
- \(H_w\) = Hours per day that waste is delivered;
- \(T_c\) = Time (in minutes) to unload each collection vehicle;
- \(F\) = Peaking factor (ratio of the number of collection vehicles received during an average 30-minute period to the number received during a peak 30-minute period);
- \(L_p\) = Length of push pit (feet);
- \(N_n\) = Number of push pits;
- \(B_c\) = Total cycle time for clearing each push pit and compacting waste into trailer;
- \(P_t\) = Transfer trailer payload (tonnes);
- \(N\) = Number of transfer trailers loading simultaneously;
- \(H_t\) = Hours per day used to load trailers (minutes);
- \(B\) = Time to remove and replace each loaded trailer (minutes);
- \(T_t\) = Time to load each transfer trailer (minutes);
- \(N_n\) = Number of hoppers;
- \(L_n\) = Length of each hopper (feet).

These formulae are useful in estimating the capacity of various types of transfer stations (EPA, 1995) and should be adapted, as necessary, for specific applications.
3.4.3 Viability

Transfer stations offer benefits such as lower collection costs (because crews waste less time travelling to the site), reduced fuel and maintenance costs for collection vehicles, increased flexibility in selection of disposal facilities, opportunity to recover recyclables or compostables at the transfer site and the opportunity to shred or scoop wastes prior to disposal. These benefits must be weighed against the costs to develop and operate the facility.

The classical approach to arrive at the economic viability of operating a transfer station, is to add the unit cost of the transfer station to the cost of hauling using large vehicles, and to compare this cost with the cost of hauling directly to the disposal site using the smaller vehicles that service the collection area. The cost of hauling using small vehicles is the sum of the depreciation cost of the vehicle, driver's salary, salary of the collection crew (if they are on standby waiting for the vehicle to return to the collection area) and fuel cost. The transfer station cost is the sum of the transfer station's depreciation cost and the operating and maintenance costs divided by the capacity of the station. The cost of using the large vehicle is the sum of the vehicle depreciation, fuel cost and driver's salary.

The cost-effectiveness of a transfer station depends on the distance of disposal site from the generation area, and a distance of 10 – 15 km is usually the minimum cost-effective distance (Phelps, et al., 1995). The distance between the disposal site and collection area is one of the principal variables in deciding whether to use a transfer station or haul the solid wastes directly from the collection area to the disposal site. Figure 3.8 illustrates the economic analysis involving the effect of the hauling distance on the collection cost:
Now, let us consider first the case in which the transfer station is located directly along the hauling route between the disposal site and the collection area. Let the unit cost of hauling using a small vehicle be $Rs. A/m^3 km$. The cost of operation, maintenance, depreciation, loading and unloading at the transfer station be $Rs. B/m^3$ and the cost of hauling using large vehicles be $Rs. C/m^3 km$. If the distance between the collection area and the transfer station is $X$ km and the distance between the transfer station and the disposal site is $Y$ km, then the distance between the collection area and the disposal site is $X + Y$ km. Then, the total cost of hauling the solid wastes from the collection area to the disposal site using a transfer station is:

$$T = 2AX + B + 2CY$$

The factor 2 is added to account for the round trip, which effectively doubles the distance travelled. The total cost of hauling without the transfer station is:

$$T_1 = 2A(X + Y)$$

The transfer station is justified, when:
\[ T < T_1 \]

That is, the hauling cost using a transfer station is lower than the direct hauling costs between the collection area and the disposal site. Substituting the values of \( T \) and \( T_1 \) yields:

\[
2AX + B + 2CY < 2AX + 2AY
\]

or

\[
Y > B/(2A - 2C)
\]

Note that \( X \) cancels out. The distance between the potential transfer station site and the disposal site is the variable to consider. The distance between the collection area and the disposal site is important in deciding the utilisation of a transfer station, if \( X \) is equal to zero, in which case the transfer station is located right at the centroid of the collection area. Under normal conditions, the centroid of the collection area has a high land value, and it would be impractical to locate a solid waste transfer station in this area. Figure 3.8 shows the effect of the distance between the potential transfer station site and the disposal site on the hauling cost.

Consider a general case in which the transfer station is located away from the hauling route between the collection area and the disposal site. Let \( Z \) be the additional distance travelled by the vehicles. The cost \( T \), when using a transfer station, is then equal to:

\[
T = B + 2AX + 2AZ + 2CY + 2CZ
\]

The cost of direct hauling from the collection area to the disposal site remains the same as previously defined. The use of a transfer station is justified, if:

\[
B + 2AX + 2AZ + 2CY + 2AZ < 2AX + 2AY
\]

or

\[
Y > (B + 2CZ + 2AZ)/(2A - 2C)
\]
Again, the decision whether or not to use a transfer station is independent of the distance between the collection area and the proposed transfer station.

LEARNING ACTIVITY 3.4

Explain the role of a transfer station in solid waste management.

Note:
 a) Write your answer in the space given below.
 b) Check your answer with the one given at the end of this Unit.
3.5 WASTE COLLECTION SYSTEM DESIGN

After we identify appropriate options for collection, equipment and transfer, we must examine the various combinations of these elements to define system-wide alternatives for further analysis. Each should be evaluated for its ability to achieve the identified goals of the collection programme. Economic analysis will usually be a central focus of the system evaluation. This initial evaluation will lead to several iterations, with the differences between the alternatives under consideration becoming more narrowly focused with each round of evaluations (EPA, 1995). After comparing the alternative strategies, the various elements like crew and truck requirement, time requirement and cost involved are calculated. The various formulae used to calculate are:

(i) **Number of services/vehicle load (N):**

\[
N = \frac{C \times D}{W}
\]

where, \( C \) = Vehicle capacity (\( m^3 \)); \( D \) = Waste density (\( kg/m^3 \))

and \( W \) = Waste generation/residence (\( kg/service \))

(ii) **Time required collecting one load (E):**

\[
E = N \times L
\]

where, \( L \) = Loading time/residence, including on-route travel

(iii) **Number of loads/crew/day (n):**

The number of loads (\( n \)) that each crew can collect in a day can be estimated based on the workday length (\( t \)), and the time spent on administration and breaks (\( t_1 \)), time for hauling and other travel (\( t_2 \)) and collection route time (\( t_3 \)).
- **Administrative and break time** ($t_1$):
  
  \[ t_1 = A + B \]

  where, \( A \) = Administrative time (i.e., for meetings, paperwork, unspecified slack time) and \( B \) = Time for breaks and lunch

- **Hauling and other travel time** ($t_2$):
  
  \[ t_2 = (n \times H) - f + G + J \]

  where, \( n \) = Number of loads/crew/day; \( H \) = Time to travel to disposal site, empty truck, and return to route; \( f \) = Time to return from site to route; \( G \) = Time to travel from staging garage to route and \( J \) = Time to return from disposal site to garage.

- **Time spent on collection route** ($t_3$):
  
  \[ t_3 = n \times E \]

  where variables have been previously defined.

- **Length of workday** ($t$):
  
  \[ t = t_1 + t_2 + t_3 \]

  where \( t \) is defined by work rules and equations A through D are solved to find \( n \).

(iv) **Calculation of number of vehicles and crews** ($K$):

\[ K = \frac{(S \times F)}{(N \times n \times M)} \]

where, \( S \) = Total number of services in the collection area; \( F \) = Frequency of collection (numbers/week) and \( M \) = Number of workdays/week

(v) **Calculation of annual vehicle and labour costs**:

Vehicle costs = Depreciation + Maintenance + Consumables + Overhead + License + Fees + Insurance
Labour costs =
Drivers salary + Crew salaries + Fringe benefits + Indirect labour + Supplies
+ Overhead

**LEARNING ACTIVITY 3.5**

Work out the time required to dispose of the waste with density 400 kg/m³, with vehicle capacity of 12 m³ and waste generation per residence is 2 kg/service and loading time per residence is 2 minutes.

**Note:**

a) Write your answer in the space given below.

b) Check your answer with the one given at the end of this Unit.

---

**3.6 RECORD KEEPING, CONTROL, INVENTORY AND MONITORING**

For effective waste collection and, indeed, SWM, we must maintain records on the quantities of wastes collected and their variation within a week, month and year, as well as on established long-term trends in solid waste generation rates
and composition, sources of wastes and the personnel collecting them. Long-term trends in solid waste generation rates and composition form the basis for planning, especially in budgeting for future vehicle requirements, allocating the collection vehicles and crew, building transfer stations, acquiring strategic lands and determining disposal options. Table 3.2 contains an illustration of a checklist of factors that affect the waste collection system:

**Table 3.2**
**Checklist of Variables Affecting Collection System**

<table>
<thead>
<tr>
<th>Components</th>
<th>Factors to Consider</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crew size</td>
<td>- labour cost</td>
</tr>
<tr>
<td></td>
<td>- distance between containers</td>
</tr>
<tr>
<td></td>
<td>- size and types of containers</td>
</tr>
<tr>
<td></td>
<td>- loading accessories available in the truck</td>
</tr>
<tr>
<td></td>
<td>- collection vehicle used</td>
</tr>
<tr>
<td>Container type</td>
<td>- solid wastes generation rate</td>
</tr>
<tr>
<td></td>
<td>- density of waste generation</td>
</tr>
<tr>
<td></td>
<td>- street width</td>
</tr>
<tr>
<td></td>
<td>- traffic volume</td>
</tr>
<tr>
<td></td>
<td>- collection crew configuration</td>
</tr>
<tr>
<td></td>
<td>- standard of living</td>
</tr>
<tr>
<td>Collection accessory</td>
<td>- labour cost</td>
</tr>
<tr>
<td></td>
<td>- protection of worker’s health</td>
</tr>
<tr>
<td>Vehicle size/type</td>
<td>- street width, traffic volume</td>
</tr>
<tr>
<td></td>
<td>- solid waste generation rates</td>
</tr>
<tr>
<td></td>
<td>- crew size</td>
</tr>
<tr>
<td></td>
<td>- viability of a transfer station</td>
</tr>
<tr>
<td>Collection route</td>
<td>- street width, traffic volume</td>
</tr>
<tr>
<td></td>
<td>- direction of traffic flow</td>
</tr>
<tr>
<td></td>
<td>- solid waste generation rates</td>
</tr>
<tr>
<td></td>
<td>- spatial distribution of wastes</td>
</tr>
<tr>
<td></td>
<td>- local topography</td>
</tr>
<tr>
<td>Transfer station</td>
<td>- distance between disposal site and collection area</td>
</tr>
<tr>
<td></td>
<td>- hauling cost for small and large trucks</td>
</tr>
<tr>
<td></td>
<td>- cost of transferring the solid wastes from small to large trucks</td>
</tr>
</tbody>
</table>

*Source: Phelps, et al., 1995*

Records of personnel and quantities of wastes collected are, when maintained, useful in determining the efficiency of the personnel and in correlating waste quantities with conditions in the service area. A time keeping system at the
transfer or disposal site is a key element in improving the efficiency of collection system and planning an upgraded system. The timekeeping system determines if the crew were taking long rest periods, spending time salvaging or carrying out unauthorised activities. The performance of a particular crew in terms of the quantity of solid wastes collected per day could be compared with that of another collection crew working under similar conditions.

The composition of solid wastes should be measured at least once a year for major districts and possibly once every two years in residential areas with stagnant growth rates and development. Changes in composition affect the collection equipment and configuration of the collection system is important in designing the disposal system. Changes in an energy source (such as a shift to gas or electricity from wood or charcoal for cooking and heating), reduces the ash content of wastes, making the solid waste lighter, in which case, larger containers could be used. The same line of analysis holds true in specifying the collection vehicles. Comparison of the routes taken by various crew serving a particular area helps to identify the best hauling route. Although this route may be longer, it could be more economical in terms of hauling time. However, note that the best route often changes with the season.

All these decisions should be based on reliable data, without which the waste collection system will inevitably be ineffective. Proper interpretation of monitoring data allows the authority to adapt the proposed system to actual conditions. In some instances, it also allows management to identify areas, where the design is not realistic.
Implementing of collection and transfer system involves the following activities, which are important for success of the plan (EPA, 1995):

(i) **Finalising and implementing the system management plan**: For proper implementation of collection and transfer system, it is necessary to have clear organisational structures and management plans. The organisational structure should be simple, with a minimum of administrative and

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**LEARNING ACTIVITY 3.6**

Discuss the practice of record keeping and monitoring with the local civic authorities of your locality and write a short report.

**Note:**

a) Write your answer in the space given below.

b) Check your answer with the one given at the end of this Unit.
management layers between collection crews and top management. All workers in the department should clearly understand the department’s mission and their roles. Through training, incentives and reinforcement by management, workers should be encouraged to be customer-oriented and team contributors. Feedback mechanisms must be introduced to help the crew review their performance and help managers monitoring the performance of crews, equipment, etc. It is also important to periodically review the management plans and structures, as implementation of collection services continues.

(ii) **Purchasing and managing equipment**: For purchasing equipment, most municipalities issue bid specifications. Detailed specifications include exact requirements for equipment sizes and capacities, power ratings, etc. Performance specifications often request that equipment be equivalent to certain available models and meet standards for capacity, speed, etc. Municipalities may either perform equipment maintenance themselves, contract with a local garage, or in some cases, contract with the vehicle vendor at the time of purchase. As part of the preventive maintenance programme, the collection crew should check the vehicle chassis, tyres and body daily and report any problems to maintenance managers. In addition, each vehicle should have an individual maintenance record that includes the following items:

- preventive maintenance schedule;
- current list of specific engine;
- a description of repairs and a list containing information on the repair date, mechanic, cost, type and manufacturer of repair parts and the length of time the truck was out of service, for each maintenance event.

(iii) **Hiring and training personnel**: As in all organisations, good personnel management is essential to an efficient, high-quality waste collection system. Authorities responsible for SWM should, therefore, strive to hire and keep well-qualified personnel. The recruitment programme should
assess applicants’ abilities to perform the types of physical labour required for the collection, equipment and methods used. To retain employees, management should provide a safe working environment that emphasises career advancement, participatory problem solving and worker incentives. Worker incentives should be developed to recognise and reward outstanding performance by employees. Ways to accomplish motivation include merit-based compensation, awards programme and a work structure. Feedback on employee performance should be regular and frequent.

Safety is especially important because waste collection employees encounter many hazards during each workday. As a result of poor safety records, insurance costs for many collection services are high. To minimise injuries, haulers should have an ongoing safety programme. This programme should outline safety procedures and ensure that all personnel are properly trained on safety issues. Haulers should develop an employee-training programme that helps employees improve and broaden the range of their job-related skills. Education should address such subjects as driving skills, first aid, safe lifting methods, identification of household hazardous wastes, avoidance of substance abuse and stress management.

(iv) **Providing public information:** Maintaining good communication with the public is important to a well-run collection system. Residents can greatly influence the performance of the collection system by co-operating in separation requirements, and by keeping undesirable materials from entering the collected waste stream. Commonly used methods of communicating information include brochures, articles in community newsletters, newspaper articles, announcements, and advertisements on radio and television, information attachments to utility bills (either printed or given separately) and school handouts. Communication materials should be used to help residents understand the community waste management challenges and the progress in meeting them. Residents should also be kept informed about issues such as the availability and costs of landfill
capacity so that they develop an understanding of the issues and a desire to help meet their waste management needs.

(v) Monitoring system cost and performance: Collection and transfer facilities should develop and maintain an effective system for cost and performance reporting. Each collection crew should complete a daily report containing the following information:

- Total quantity hauled.
- Total distance and travel times to and from the disposal site.
- Amounts delivered to each disposal, transfer, or processing facility.
- Waiting time at sites.
- Number of loads hauled.
- Vehicle or operational problems needing attention.

Collected data should be used to forecast workloads, truck costs, identify changes in the generation of wastes and recyclables, trace the origin of problematic waste materials and evaluate crew performance. Just as the goals of a collection programme set its overall directions, a monitoring system provides the short-term feedback necessary to identify the corrections needed to achieve those goals.

In brief guidelines for planning waste collection and transport are given below:

- Analyse the quantum of waste generated with composition.
- Capacity building of town municipalities with appropriate infrastructure and the knowledge of existing laws or regulations on waste collection, transport and safe disposal.
- Designate a para-state agency to oversee waste collection, transport and disposal to avoid confusion among para-state government agencies.
- Determine geographic scope of collection and transport services.
- Determine funding, equipment and labour needs.
- Determine the type and amount of waste to be processed.
• Implement decentralised waste treatment through proven local techniques
• Deploy GPS (Global Positioning System) based trucks for waste collection and transport to minimise pilferages.
• Adopt spatial information system for the management
• Consider a transfer station that serves as a central location for activities to sort and recover waste.
• Implement decentralised waste management including all stakeholders with active participation of the public.
3.8 THE CASE OF BANGALORE

In the Bangalore city (India), the waste collected through street sweeping is the main system of primary collection of wastes. However, recently efforts are being made for doorstep collection of waste through NGOs (Non-Governmental Organisations) and private contractors, but only about 5% of the population is covered under this system. The waste generated by the rest is collected from...
either the street or the dustbins. Other details regarding the collection process in Bangalore are given below:

(i) **Waste storage:** There are about 14,000 bottomless cement bins having 0.9 meters diameter and 0.6 cubic meter storage capacity and large masonry bins for depositing wastes at a distance of about 100 to 200 meters. Besides these, there are 1500 places, where the waste is deposited but no bins are kept on these sites. Recently, metal containers have been placed and at present 55 metal containers are in the city for the storage of waste in a more hygienic manner.

(ii) **Waste collection:** The frequency of removal of wastes varies from place to place, depending on the locality. Whichever system adapted in the area needs proper planning for collection, loading, unloading and transportation from transfer station and to the point of final disposal, considering traffic constraints, peak hour traffic, etc. An optimum collection schedule requires to be worked out where the number of premises or dumps is mentioned on a daily programme sheet, to be executed by the driver or supervisor in charge of collection. At present, it is estimated that there are about 4943 hotels/restaurants, which produce a large quantity of organic wastes in Bangalore. The silt and waste removed from drains get deposited along the roadside. The human and animal excreta also add to the mass getting deposited on streets. Mechanical sweeping or cleaning cannot work in Bangalore roads and footways because of obstructions due to the activities of hawkers, shop extensions, broken pavements, etc. Pedestrians, shops, goods vehicles carrying loose materials contribute to street littering of paper, used tickets, cigarette butts, etc., as well as vehicles dropping material during their movement (http://stratema.sigis.net/cupum/pdf/E1.pdf).

(iii) **Waste transportation:** Removal of garbage is a very important aspect of SWM, and the method of transportation is crucial. In essence, any breakdown in this system could create problems. Transportation implies conveyance from point of collection to the point of final disposal either
directly or through a transfer system. In Bangalore, the transportation of waste is done by:

- engaging, departmentally, 82 trucks of the Corporation.
- engaging 129 vehicles, on contract, for layout and markets and 72 vehicles for transportation of waste. (In addition, the Bangalore Corporation has 13 dumper placers for transporting metallic containers of 2.5 to 3 tonnes capacity and 6 mini-compactors for transportation of waste.)

The clearing efficiency is 30 to 35%. The vehicles are open and the spillage of waste on the roads is a common feature. Each truck makes two trips to the dumpsite everyday. There are no transfer stations in Bangalore. The waste collected from the roads and bins is directly transported to the final disposal sites. There is no arrangement made for the primary collection of construction waste. The engineering division of the Corporation removes the unauthorised construction waste from time to time. There are 115 small and big vegetable, fruit and meat markets in the city. However, no special arrangements are made for the collection of waste from these markets.
In this Unit, our focus was on waste collection systems. We discussed in detail the various components of waste collection system including collection frequency, storage containers, collection route and transfer station. We also discussed the viability of establishing and maintaining transfer stations. During the course of our discussion on the movement of collection vehicles and crew, we brought out the usefulness of the MTM technique to achieve efficiency in vehicle and crew movement. We also discussed the design, operation and implementation aspects of waste collection systems. We closed the Unit with the case study of Bangalore.
SUGGESTED READINGS


http://ces.iisc.ernet.in/energy/SWMTR/TR85.html

http://wgbis.ces.iisc.ernet.in/energy/paper/researchpaper.html#sw

REFERENCES


LEARNING ACTIVITY 3.1

Bangalore Mahanagara Palike (BMP) undertakes the waste collection system in our locality.

Solid waste collection starts at the point of waste generation. Wastes are stored in bottomless concrete containers placed 100 meters apart for which covers are not provided. Wastes are collected in trucks of 4 to 5 tonnes capacity. Collection frequency is based on the requirement of the locality. Since our locality is mostly residential, collection of waste is done three times a week. The collection crew consists of a driver and two helpers. The collection route for our locality is entirely left to the driver's judgement.

Collection is often the most costly component of the solid waste management system and a proper collection system design and management can reduce the cost significantly. In terms of cost, the collection system in developing countries accounts for 70 – 80% of the total budget for solid waste management, the remaining 20 – 30% going for overheads. While making decisions for alternative collection systems, the services must be evaluated considering such factors as efficiency, effectiveness, equity, reliability, safety and environmental impacts.

LEARNING ACTIVITY 3.2

The types of containers used in our locality are uncovered bottomless concrete rings having 0.9 meters diameter and 0.6 cubic meter storage capacity. They are placed 100 – 200 meters apart. The collection vehicle used is a truck of 4 – 5 tonne capacity and is enclosed by an iron mesh at the top to prevent the spillage of wastes.
LEARNING ACTIVITY 3.3

The heuristic (trial and error) route development process is a relatively manual approach that applies specific routing patterns to block configurations. Routes are to be traced on the tracing paper by following certain rules. Routes should not be fragmented or overlapping. Each route should be compact, consisting of street segments clustered in the same geographical area. In streets with heavy traffic, wastes should not be collected during peak hours. Higher elevations should be at the start of the route. Waste on a steep hill should be collected, when practical, on both sides of the street while vehicle is moving downhill. This facilitates safe, easy and fast collection. In case of one-way streets, it is best to start near the upper end of the street, working down it through the looping process. Services on dead end streets can be considered as services on the street segment. To keep right turns at a minimum, collect the dead-end streets when they are to the left of the truck. They must be collected by walking down, backing down or making a U-turn.

LEARNING ACTIVITY 3.4

Transfer station is a centralised facility where waste is unloaded from smaller collection vehicles and reloaded into large vehicles for transport to a disposal or processing site. To determine whether a transfer system is viable for a particular community, the decision-makers should compare the costs and savings associated with the construction and operation of a transfer facility. The use of transfer station is a sound practice when there is a need for vehicles servicing a collection route to travel a shorter distance, unload and return quickly to their primary task of collecting the waste. There are 3 types of stations depending on the capacity, viz., small capacity (less than 100 tonnes/day), medium capacity (100 to 500 tonnes) and large capacity (more than 500 tonnes). Some of the factors that should be considered in determining the appropriate size of a transfer facility include the capacity of collection vehicles, time required to unload, waste sorting, hours of station operation and time required to connect and disconnect the trailers from compactors.
LEARNING ACTIVITY 3.5

Convert 400 kg/m$^3$ to tonnes, i.e. $400/1000 = 0.4$ tonnes/m$^3$

(i) Number of services/vehicle load (N)
\[
N = \frac{C \times D}{W}
\]
\[
= \frac{12 \times 0.4}{2}
\]
\[
= 2.4 \sim 2
\]

(ii) Time required to collect the load
\[
E = N \times L
\]
\[
= 2 \times 2
\]
\[
= 4 \text{ minutes}
\]

LEARNING ACTIVITY 3.6

The solid waste collection in our ward is undertaken by a private contract system, and Bangalore Mahanagara Palike (BMP), which has appointed a Medical Health officer, a Senior Health Inspector, a Junior Health Inspector and Sanitary Daffedars, assists the private contractor. They have employed pourakarmikas for sweeping and collection of wastes from households and containers. The Health Inspectors are in charge of the muster roll. Workers assemble at 6:30 a.m. in the morning at a specified place. Each worker is given the equipment and the section of the ward, which he or she has to clean. Work ends at 10:30 a.m. and the workers assemble at the same place to give their muster roll. From 11 a.m. to 1:30 p.m. gang work is carried out in a particular area or even a whole ward depending on the need. The need may be a clogged drain or clearing of black spots. The attendance of each of the workers is recorded at the field by the inspectors. There is another muster roll at 1:30 p.m. At present records are not maintained on the quantity of wastes collected and their variation. Once in a while, the contractor of our ward is asked to determine the quantity of waste generated per day.
LEARNING ACTIVITY 3.7

The activities responsible for successful implementation of collection and transfer systems are as follows:

- Finalising and implementing the system management plan.
- Purchasing and management of equipment.
- Hiring and training personnel.
- Providing public information.
- Monitoring system cost and performance.

LEARNING ACTIVITY 3.8

(i) If the crew can service 2 customers in one minute, then in 4 hours (i.e., $4 \times 60$ minutes) the crew can service:

$$\frac{2}{1} = \frac{X}{4 \times 60}$$

$X = 480$ customers per day.

(ii) The number of collection vehicles needed for a community is given by:

$$N = \frac{SF}{XW}$$

Where $N =$ number of collection vehicles required; $S =$ total number of households serviced $= 10,000$; $F =$ collection frequency, number of collections per week $= 1$; $X =$ number of households a single truck can service per day $= 4$ and $W =$ number of workers per week $= 250$.

Therefore $N = \frac{10000 \times 1}{250 \times 4}$, i.e., the corporation ward requires ten collection vehicles.