B.Sc. Course(First Semester)
University of Babylon-College of Engineering
Environmental Engineering Department

Chapter Six (Solid Waste Management)

Collection Of Solid Waste

6.1 Waste Collection

The term collection, includes not only the gathering or picking up of solid wastes from the various sources, but also the hauling of these wastes to the location where the contents of the collection vehicles are emptied. The unloading of the collection vehicle is also considered part of the collection operation.

From Low-Rise Detached Dwellings:

The most common types of residential collection services for low-rise detached dwellings include:

1. Curb
2. Alley
3. Setout-setback, and
4. Setout

Where ***curb*** service is used, the homeowner is responsible for placing the containers to be emptied at the curb on collection day and for returning the empty containers to their storage location until the next collection figures(6.1 , 6.2)

Where ***alleys*** are part of the basic layout of a city or a given residential area, alley storage of containers used for solid waste is common.

In ***setout-setback*** service, containers are set out from the homeowner's property and set back after being emptied by additional crews that work in conjunction with the collection crew responsible for loading the collection vehicle.

Setout service is essentially the same as setout-setback service, except that the homeowner is responsible for returning the containers to their storage location.

From ***Low-and Medium-Rise Apartments.*** Curbside collection service is common for most low-and medium-rise apartments. Where large containers are used the containers are emptied mechanically using collection vehicles equipped with unloading mechanisms.

From ***High-Rise Apartments.*** Typically, large containers are used to collect wastes from large apartment buildings.

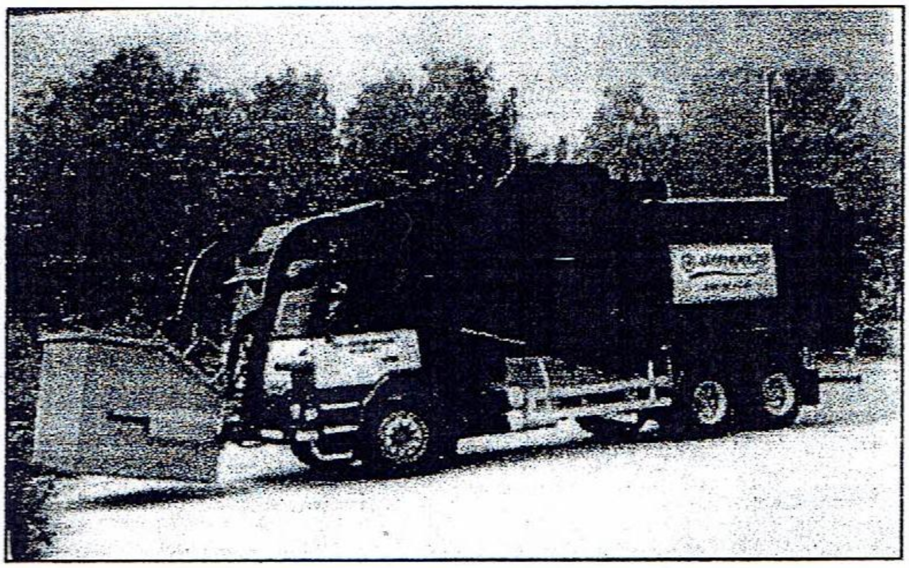


Fig.6.1: Typical example of mechanically loaded collection vehicle used for the collection of residential wastes

From ***Commercial-Industrial Facilities:*** Both manual and mechanical means are used to collect wastes from commercial facilities-To avoid traffic congestion during the day, solid wastes from commercial establishments in many large cities are collected in the late evening and early in early morning hours.

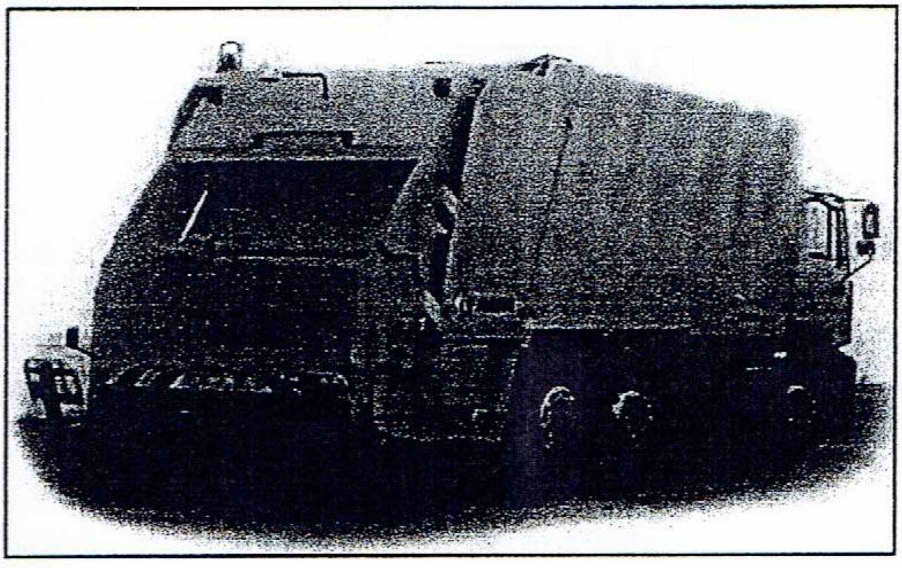


Fig.6.2: Collection vehicle

6.2 Types Of Collection Systems, Equipment And Personnel

Collection systems have been classified according to their mode of operation into two categories:

1. Hauled container systems (HCS) and
2. Stationary container systems (SCS)

In the former, the containers used for the storage of wastes are hauled to the disposal site, emptied, and returned to either their original location or some other location. In the latter, the containers used for the storage of wastes remain at the point of generation, except when they are moved to the curb or other location to be emptied.

Hauled Container Systems:

Hauled container systems are ideally suited for the removal of wastes from sources where the rate of generation is high, because relatively large containers are used. The use of large containers reduces handling time as well as the unsightly accumulations and unsanitary conditions associated with the use of numerous smaller containers. There are three main types of hauled container systems:

1. Hoist truck,(Fig 6.3)
2. Tilt-frame loading(Fig 6.4), and
3. Trash-trailer(Fig6.5)

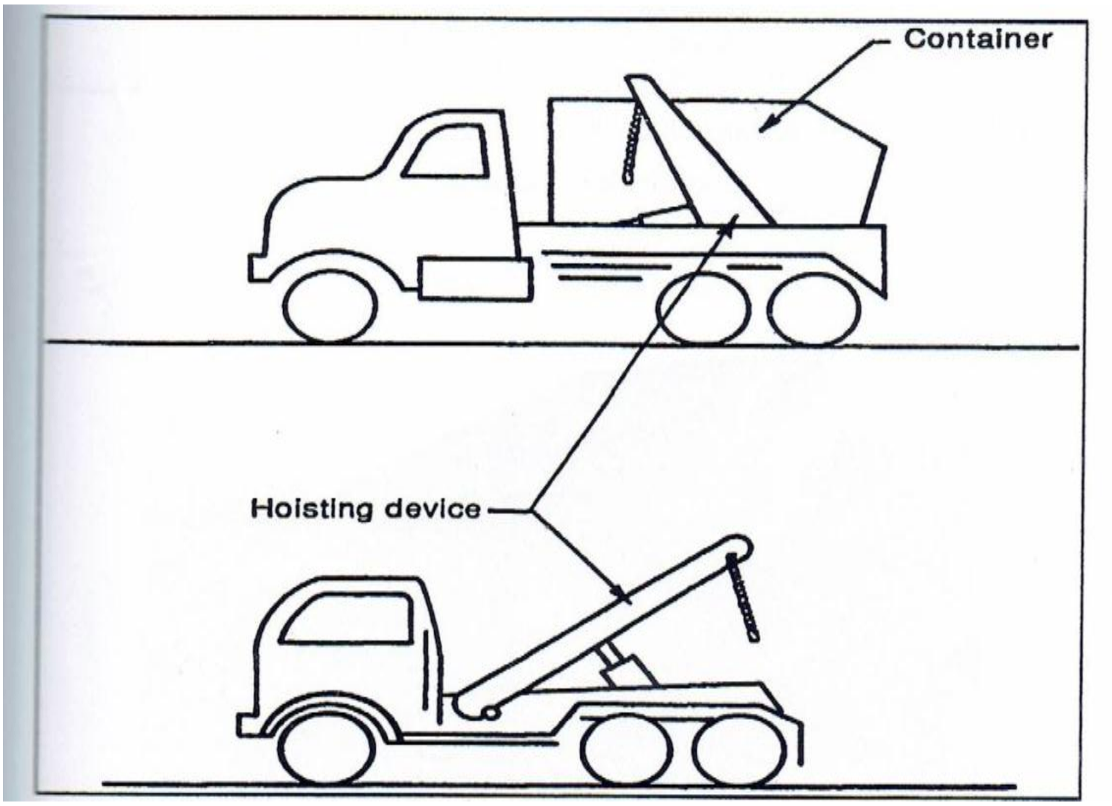


Fig.6.3: hoist-type equipment or hoist equipment, the hoist arms, chains, and frames used to elevate, support, transport, dump, and unload refuse containers.

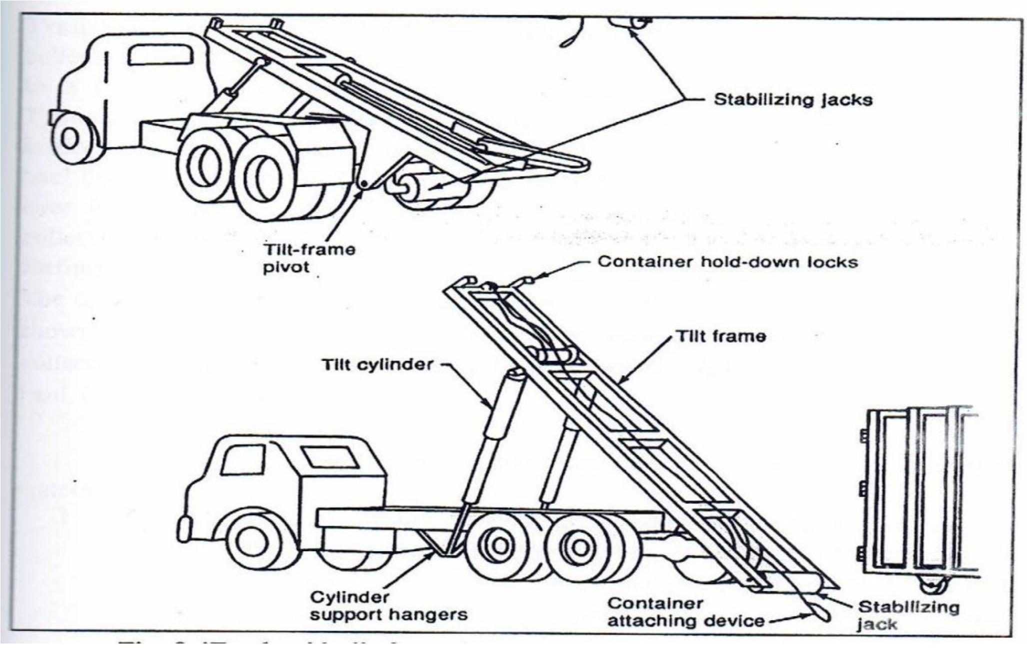


Fig.6.4:Truck with tilt-frame loading mechanism used to haul and unload large-capacity containers.

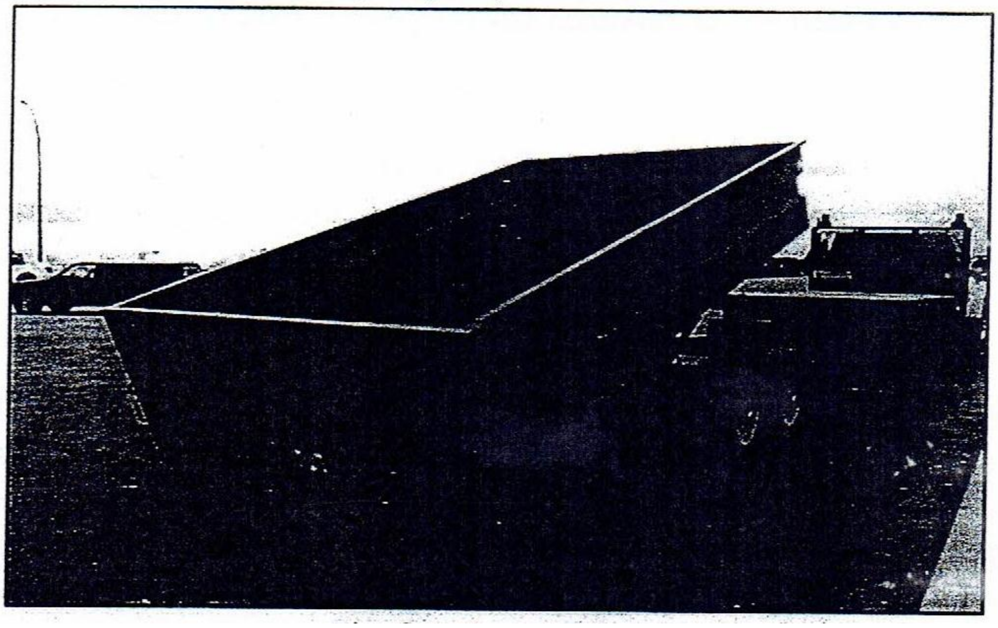


Fig.6.5:Trash-trailer

Transfer Operation:

Transfer operations, in which the wastes, containers, or collection vehicle bodies holding the wastes are transferred from a collection vehicle to a transfer or haul vehicle, are used primarily for economic considerations.

Transfer operations may prove economical when:

1. Relatively small, manually loaded collection vehicles are used for the collection of residential wastes and long haul distances are involved,

2. Extremely large quantities of wastes must be hauled over long distances, and
3. One transfer station can be used by a number of collection vehicles.

Definition of Terms:

The operational tasks for the hauled container and stationary container systems are shown schematically in Fig6.5 and Fig6.6, respectively. The activities involved in the collection of solid wastes can be resolved into four unit operations:

1. Pickup.
2. Haul,
3. At-site, and
4. Off-rout.

Pickup:

The definition of the term pickup depends on the type of collection system used:

1. For hauled container systems operated in the conventional mode (see Fig6.6a), ***pickup(P_{hcs})*** refers to the time spent driving to the next container after an empty container has been deposited, the time spent picking up the loaded container, and the time required to redeposit the container after its contents have been emptied. For hauled container systems operated in the exchange container mode (see Fig6.6b), pickup includes the time required to pick up a loaded container and to redeposit the container at the next location after its contents have been emptied.
2. For stationary container system (see Fig6.7), pickup(Pscs) refers to the time spent loading the collection vehicle, beginning with stopping the vehicle before loading the contents of the first container and ending when the contents of the last container to be emptied have been loaded.

Haul:

The definition of the term haul(h) also depends on the type of collection system used.

1. For hauled container systems, haul represents the time required to reach the location where the contents of the container will be emptied (e.g., transfer station, disposal site), starting when a container whose contents are to be emptied has been loaded on the truck and continuing through the time after leaving the unloading location until the truck arrives at the location where the empty container is to be deposited. Haul time does not include any time spent at the location where the contents of the container are unloaded.

2. For stationary container systems, haul refers to the time required to reach the location where the contents of the collection vehicle will be emptied(e.g., transfer station, or disposal site), starting when the last container on the route has been emptied or the collection vehicle is filled and continuing through the time after leaving the unloading location until the truck arrives at the location of the first container to be emptied on the next collection route. Haul time does not include the time spent at the location where the contents of the collection vehicle are unloaded.

At-Site:

The unit operation at-site(S) refers to the time spent at the location where the contents of the container (hauled container system) or collection vehicle (stationery container system) are unloaded(e.g., transfer station, MRF, or disposal site) and includes the time spent waiting to unload as well as the time spent unloading the wastes from the container or collection vehicle.

Off-Route:

The unit operation off-route(W) includes all time spent on activities that are nonproductive from the point of view of the overall collection operation. Many of the activities associated with off-route times are sometimes necessary or inherent in the operation. Therefore, the time spent on off-route activities may be subdivided into two categories: necessary and unnecessary. In practice, however, both necessary and unnecessary off-route times are considered together because-they must be distributed equally over the entire-operation.

1. Necessary off-route time includes:

a. Time spent checking in and out in the morning and at the end of the day,
b. Time lost due to unavoidable congestion, and
c. Time spent on equipment repairs, maintenance, and so on.

2. Unnecessary off-route time includes:

Time spent for lunch in excess of the stated lunch period; and time spent on taking unauthorized coffee breaks, talking to friends, and the like.

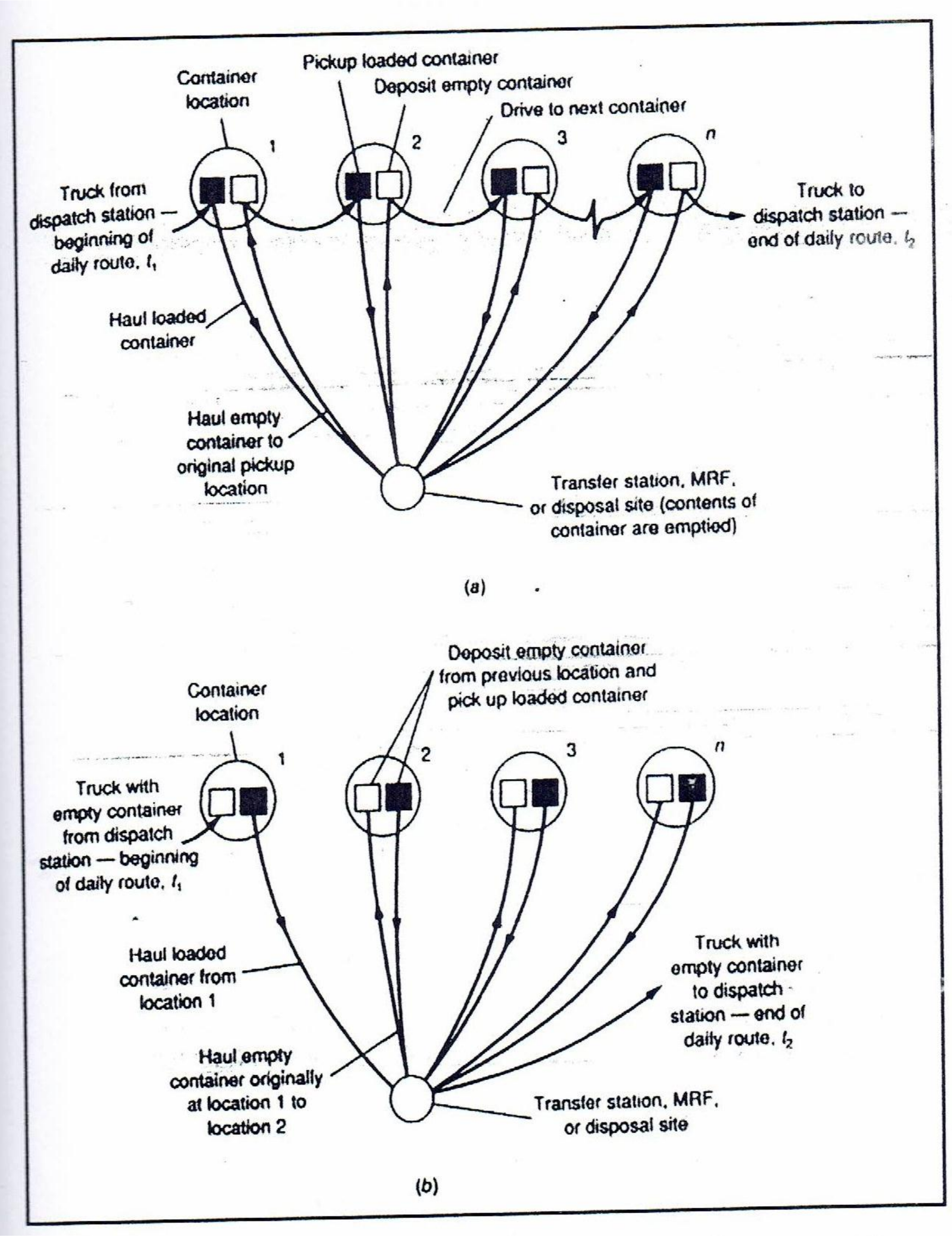


Fig6.6: Schematic of operational sequence for hauled container system: (a) conventional mode and (b) exchange container mode.

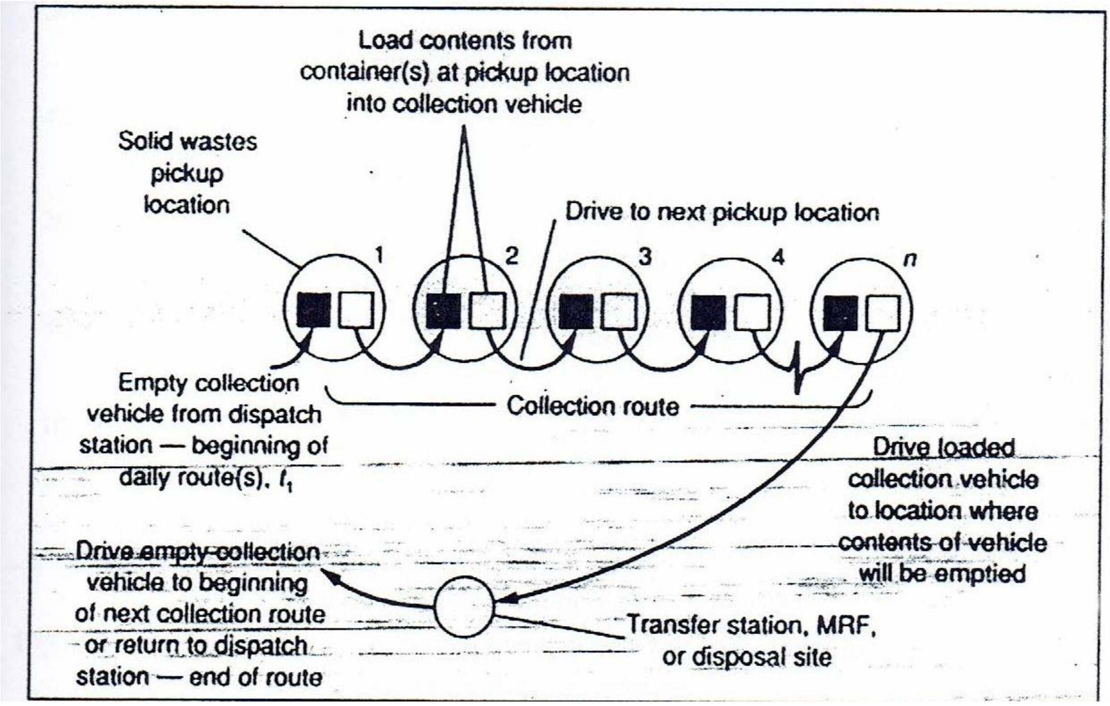


Fig6.7: Schematic of operational sequence for stationary container system

Hauled Container System calculations:

Haul time is given by the following equation

$$T_{hcs} = (P_{hcs} + s + h) \qquad (6.1)$$

Where:

T_{hcs}=time per trip for hauled container system, h/trip

P_{hcs}=pickup time per trip for hauled container system, h/trip

s=at-site time per trip. h/trip,

h=haul time per trip, h/trip

For hauled container systems the pickup and at-site times are relatively constant, but the haul time depends on both haul speed and distance. From an analysis of a considerable amount of haul data for various types of collection vehicles (see Fig6.8), it has been found that the haul time h may be approximated by the following expression:

$$h = a + bx \qquad (6.2)$$

where:

h=total haul time, h/trip

a=empirical haul-time constant, h/trip

b=empirical haul-time constant, h/mi

x=average round-trip haul distance, mi/trip

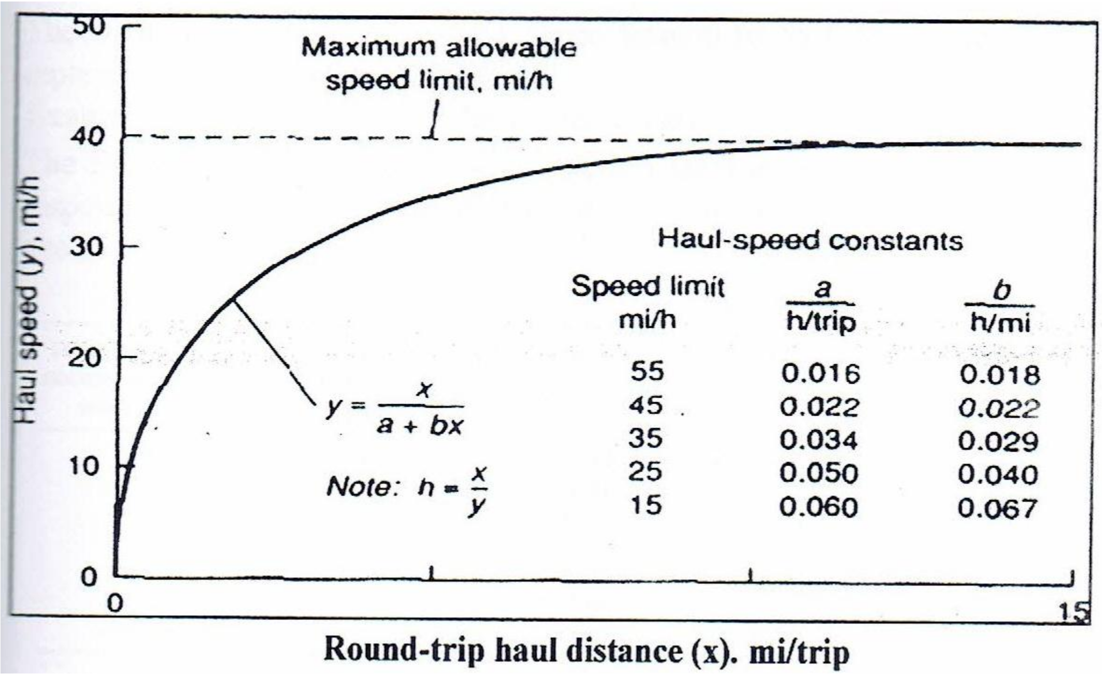


Fig6.8: Correlation between average haul speed and round-trip haul distance for waste collection vehicles.

The time per trip can be expressed as follows;

$T_{hcs} = (P_{hcs} + s + a + bx)$ ……………………..…………………………………………….………..(6.3)

The pickup time per trip, P_{hcs}, for the hauled container system is equal to :

$P_{hcs} = pc + uc + dbc$ ………………………………………………………………….…………..(6.4)

Where:

P_{hcs}=pickup time per Trip, h/trip

pc=time required to pick up loaded container, h/trip

uc=time required to unload empty container, h/trip

dbc=time required to drive between container locations, h/trip

the number of trips that can be made per vehicle per day with a hauled container system, taking into account the off-route factor W, can be determined by using Eq.(6.5):

$Nd = [H(1-W)-(t_1+t_2)]/T_{hcs}$ ……………………………………………………………(6.5)

Where:

Nd=number of trips per day, trips/d

H=length of work day, h/d

W=off-route factor, expressed as a fraction

t_1=time to drive from dispatch station (garage) to first container location to be serviced for the day, h

t_2=time to drive from the last container location to be serviced for the day to the dispatch station(garage), h

Thcs=pickup time per trip, h/trip

The off-route factor in Eq(6.5) varies from 0.10 to 0.40; a factor of 0.15 is representative for most operations.

Example6.1: Determination of haul-speed constants.

The following average speeds were obtained for various round-trip distances to a disposal site. Find the haul-speed constants a and b and the round-trip haul time for a site that is located 11.0 mi away.

Round-trip distance (x), mi/trip	Average haul speed (y), mi/h	Total time (h = x/y), h
2	17	0.12
5	28	0.18
8	32	0.25
12	36	0.33
16	40	0.40
20	42	0.48
25	45	0.56

Solution:

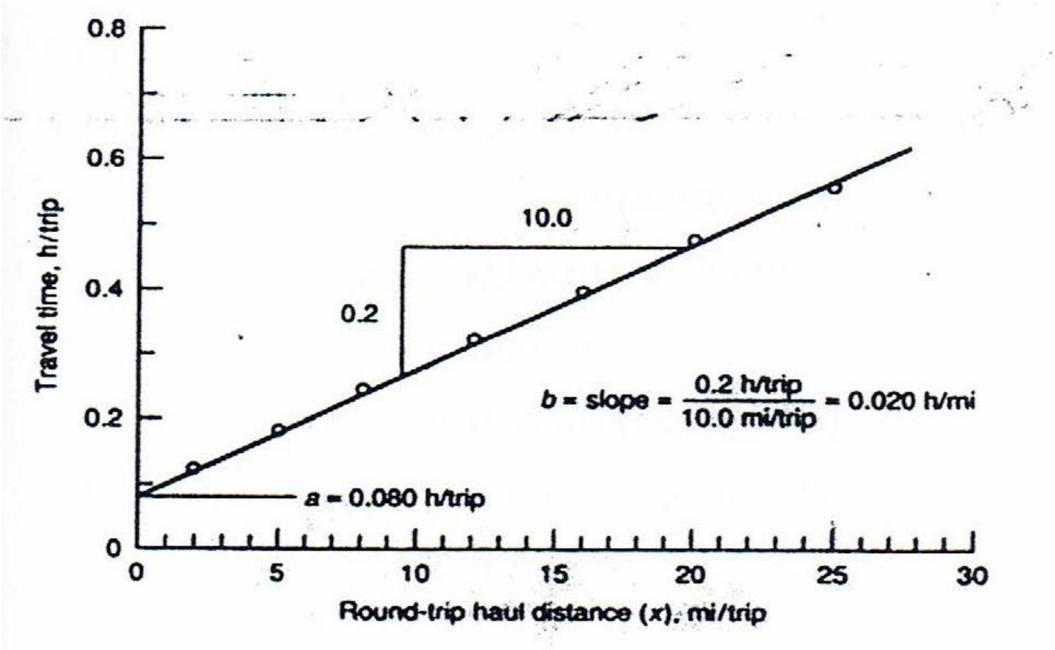
1. Linearize the haul-speed equation given in Fig6.8. the basis haul-speed equation (a rectangular hyperbola) is:

$$y = \frac{x}{a+bx}$$

The linearized from of this equation is:

$$\frac{x}{y} = h = a + bx$$

3. Plot x/y , which is the total haul travel time versus the round-trip distance as shown below.



4. Determine the haul-time constants a and b. when x=0, a=intercept value=0.080 h/trip, b=slope of line=(0.2 h/trip)/(10 mi/trip)=0.020 h/mi(0.012 h/km).
5. Find the round –trip haul time for a site that is located 11.0 mi away.

Round-trip distance=2(11.0 mi/trip)=22 mi/trip

$Round - trip\ haul\ time\ h = a + bx$

$= 0.080\, h/trip + (0.020\ \ h/mi)(22\ \ mi/trip) = 0.52\ \ h/trip$

Example6.2: Analysis of hauled container system.

Solid waste from a new industrial park is to be collected in large containers (drop boxes), some of which will be used in conjunction with stationary compactors. Based on traffic studies at similar parks, it is estimated that the average time to drive from the garage to the first container location (t_1) and from the last container location(t_2) to the garage each day will be 15 and 20 min, respectively. If the average time required to drive between containers is 6min and the one-way distance to the disposal site is 15.5 mi (speed limit:55mi/h), determine the number of containers that can be emptied per day, based on an 8h work day. Assume the off-route factor, W, is equal to 0.15.

Solution:

1. Determine the pickup time per trip using Eq (6.4)

$P_{hcs} = pc + uc + dbc$

$Use\ pc + uc = 0.4\, h/trip\ (see\ Table\ 3)$

$dbc = 0.1\ h/trip\ (given)$

$P_{hcs} = (0.4 + 0.1)\ h/trip = 0.5\ h/trip$

2. Determine the time per trip using Eq (6.3).

$T_{hcs} = (P_{hcs} + s + a + bx)$

$P_{hcs} = 0.5\ h/trip\ \ (from\ Step1)$

$s = 0.133\ h/trip\ \ (from\ Table\ 3)$

$a = 0.016\ h/trip\ \ (see\ Fig\ 6.8)$

$b = 0.018\ h/trip\ \ (see\ Fig\ 6.8)$

$T_{hcs} = [0.5 + 0.133 + 0.016 + 0.018(15.5 \times 2)]\ h/trip = 1.21\ h/trip$

3. Determine the number of trips that can be made per day using Eq.(6.5)

$Nd = [H(1 - W) - (t_1 + t_2)]/T_{hcs}$

$Use\ H = 8\ h\ (given)$

$W = 0.15\ (assumed)$

$t_1 = 0.25\ h\ (given)$

$t_2 = 0.33\ h\ (given)$

$T_{hcs} = 1.21\ h/trip$

$Nd = [8(1 - 0.15) - (0.25 + 0.33)]/(1.21\ h/trip)$

$= (6.8 - 0.58)/(1.21\ h/trip) = 5.14\ trips/d$

$Use\ Nd = 5.0\ trips/d$

4. Determine the actual length of the workday.

$5.0\ trips/d = [H(1 - 0.15) - 0.58]/(1.21\ h/trip)$

$H = 7.80\ h\ (essentialiy\ 8h)$

6.3 Collection Routes

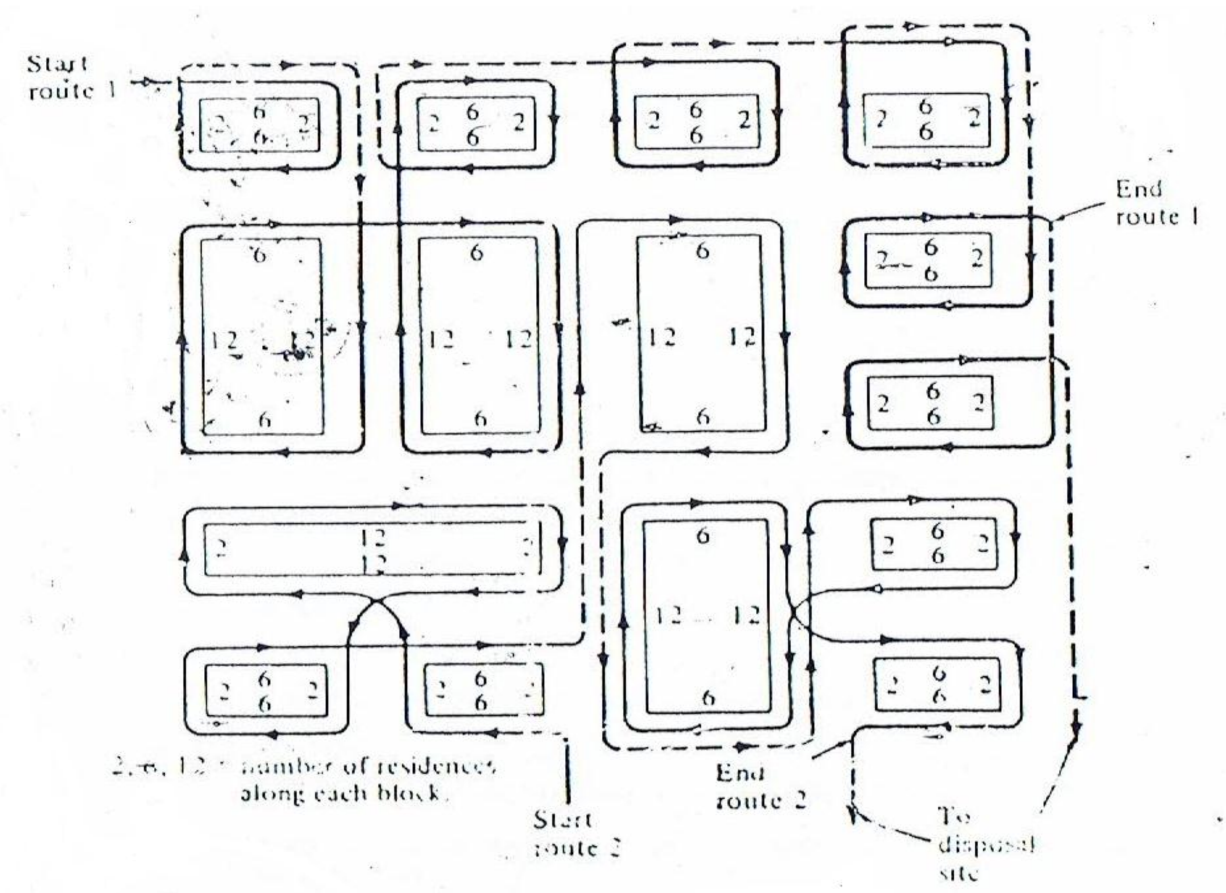
Once equipment and labor requirements have been determined, collection routes, must be laid out so that both the collectors and equipment are used effectively. In general, the layout of collection routes involves a series of trials. There is no universal set of rules that can be applied to all situations. Thus, collection vehicle routing remains today a heuristic (common sense) process. Some heuristic guidelines that should be taken into consideration when lying out routes are as follows:

1. Existing policies and regulations related to such items as the point of collection and frequency of collection must be identified.
2. Existing system characteristics such as crew size and vehicle types must be coordinated.
3. Wherever possible, routes should be laid out so that they begin and end near arterial streets, using topographical and physical barriers as route boundaries.
4. In hilly area, routes should start at the top of the grade and proceed downhill as the vehicle becomes loaded.
5. Routes should be laid out so that the last container to be collected on the route is located nearest to the disposal site.
6. Wastes generated at traffic-congested locations should be collected as early in the day as possible.
7. Sources at which extremely large quantities of wastes are generated should be serviced during the first part of the day.
8. Scattered pickup points(where small quantities of solid waste are generated)that receive the same collection frequency should, if possible, be serviced during one trip or on the same day.

Example6.3: Laying collection routes.

Layout collection routes for the residential area shown in the accompanying figure. Assume the following data are applicable.

1. General
   a. Occupants per resident=3.5
   b. Solid waste generation rate =1.6 kg/ person. d
   c. Collection frequency=one/wk
   d. Type of collection service =curb
   e. Collection crew size = one person
   f. Collection vehicle capacity=20m^3
   g. Compacted density of solid wastes in collection vehicle = 325 kg/m^3
2. Route constraints
   a. No U-turns in streets
   b. Collection from each side of street with stand-up right hand drive collection vehicle



Solution:

1. Determine total number of residences from which wastes are to be collected.

$$Residences = 10(16) + 4(36) + 1(28) = 332$$

2. Determine the compacted volume of solid waste to be collected per week.

$Vol(wk)$

$= (332\ residences \times 3.5\ persons/residence \times 1.6\ kg/person.d\ \times 7\ d/wk)/325\ kg/m^3$

$= 40.0\ m^3/wk$

3. Determine the number of trips/wk.

$$Trip/wk = (40.0\ m^3/wk)/(20\ m^3/trip) = 2$$

4. Determine the average number of residences from which wastes are to be collected each day.

$$\text{Residences}/Trip = 332/2 = 166$$

5. Lay out collection routes by trial and error using the route constraints cited above as a guide. The two routes are shown in the figure.

Comment: It should be noted that there is no single correct solution to this problem. It just works out that some solutions are better than others when they are implemented. It is only with experience that an intuitive sense can be developed about the layout of collection routes.