COLLECTION OF SOLID WASTES

Collection of solid waste in urban areas is difficult and complex **because the generation of residential, commercial and industrial solid waste is a diffuse process that takes place in every home, every apartment building and every commercial and industrial facility as well as in the streets, parks, and even vacant areas of every community. The like development of suburbs all over the country has further complicated the collection task.**

Collection Services includes not only the gathering of solid wastes, but also the hauling of wastes after collection to the location where the collection vehicle is emptied. Collection of solid wastes is one of the most costly functional elements, because of high cost of fuel and labor.

Type of solid Waste collection services

Various types of collection services now used for municipal, commercial, and industrial sources. The most common municipal collection systems are curb, alley and backyard collection. The collection service provided to large apartment buildings, residential complexes and commercial and industrial activities typically centered on the use of large movable and stationary containers.

- **Curb Service (kerb-side):** The house owner is responsible for placing the solid waste containers at the curb on the scheduled day. The workers come, collect, and empty the container and put back at the curb. Curb collection has gained popularity because labor cost for collection can be minimized. In the future it appears that the use of large containers which can emptied mechanically with an articulated containers pick up mechanism will be the most common method used for the collection of municipal wastes.

- House owner is responsible for take back the empty container to his house.
- Quickest/economical
- Crew 1 driver + 1or 2 collectors
- No need to enter the property

- **Alley Service:** The containers placed at the alley line from where they are picked up by workers from refuse vehicle who deposit back the empty container.
- **Set out set back service:**
  - Collectors have to enter the property
  - Set out crew carries full containers from resident storage location to curb\alley before collection vehicle arrives
  - Set-back return the containers to the storage area
- **Backyard Service:**

- Workers with the vehicle carry a bin, wheelbarrow, sack, or cloth to the yard and empty the solid waste container in it.
- The bin is taken to solid waste vehicles where it emptied.

See Figures 1, 2.

(a)

Fig.1. Collection of wastes from containers placed at curb by homeowner (a) with a side-loading vehicle equipped with a right-hand drive mechanism, and (b) with rear-loading collection vehicle. The rear-loaded type of collection vehicle is commonly used with two- and three- person crews for the collection residential wastes in many parts of the United States.

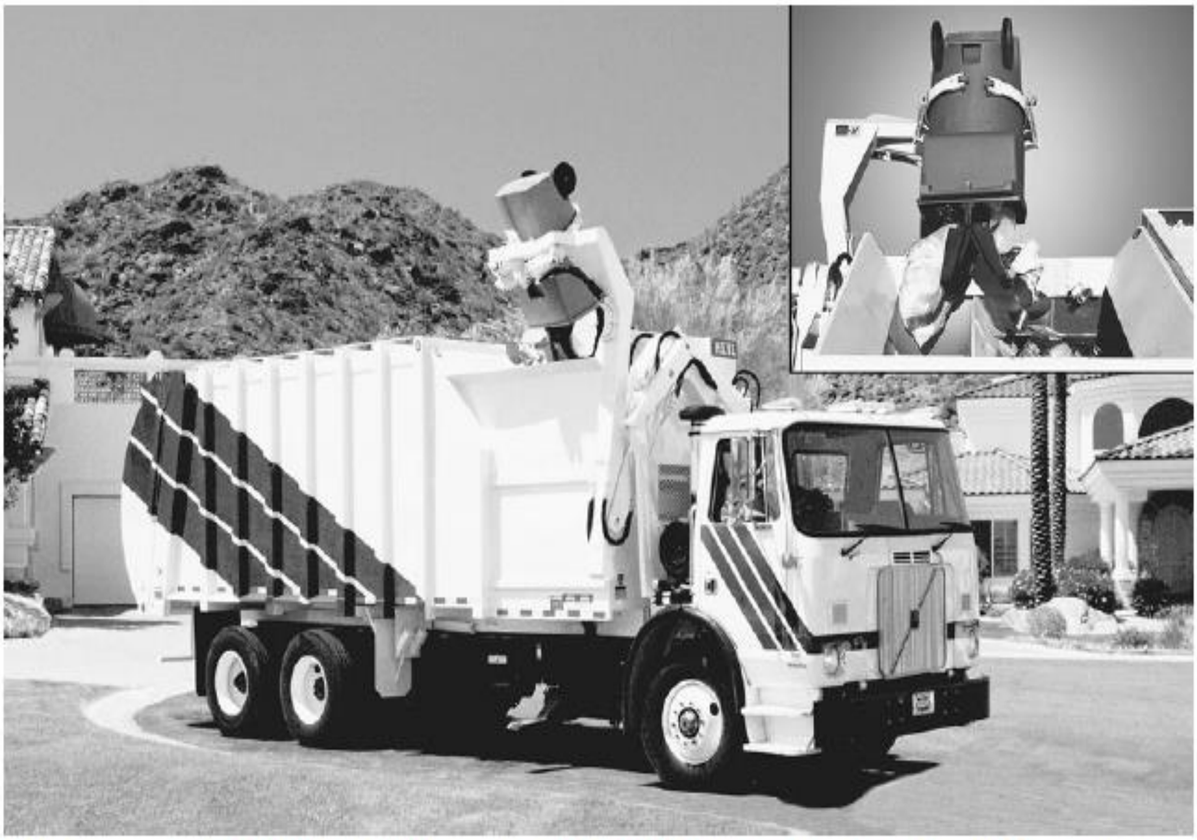

Fig. 2. Typical example of mechanized collection vehicle with mechanical articulated pickup mechanism used for the collection of domestic source waste

Types of collection systems

Solid waste collection system may be classified from several point of view such as the mode of operation, the equipment used, and the types of waste collected. In this text collection, system has been classified according to their mode of operation.

Hauled – container systems

Stationary- container systems

Hauled Container Systems (HCS)

Hauled Collection system in which the containers used for the storage of waste are hauled to the processing, transfer or disposal site, emptied and returned to either their original location or some other location. Fig. 3

Stationary –Container System (SCS)

Stationary Collection system in which the containers used for the storage of wastes remain at the point of waste generation, except when moved for collection.

There are two main types of stationary- container systems :(1) those in which self-loading compactors are used, and (2) those in which manually loaded vehicles are used. Fig.4

Hauled Container System and equipment

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 eliminates time as well as the unsightly accumulations and unsanitary conditions associated with the use of numerous smaller containers. Another advantage of hauler container system is flexibility: Containers of many different sizes and shapes are available for the collection of all types of wastes.

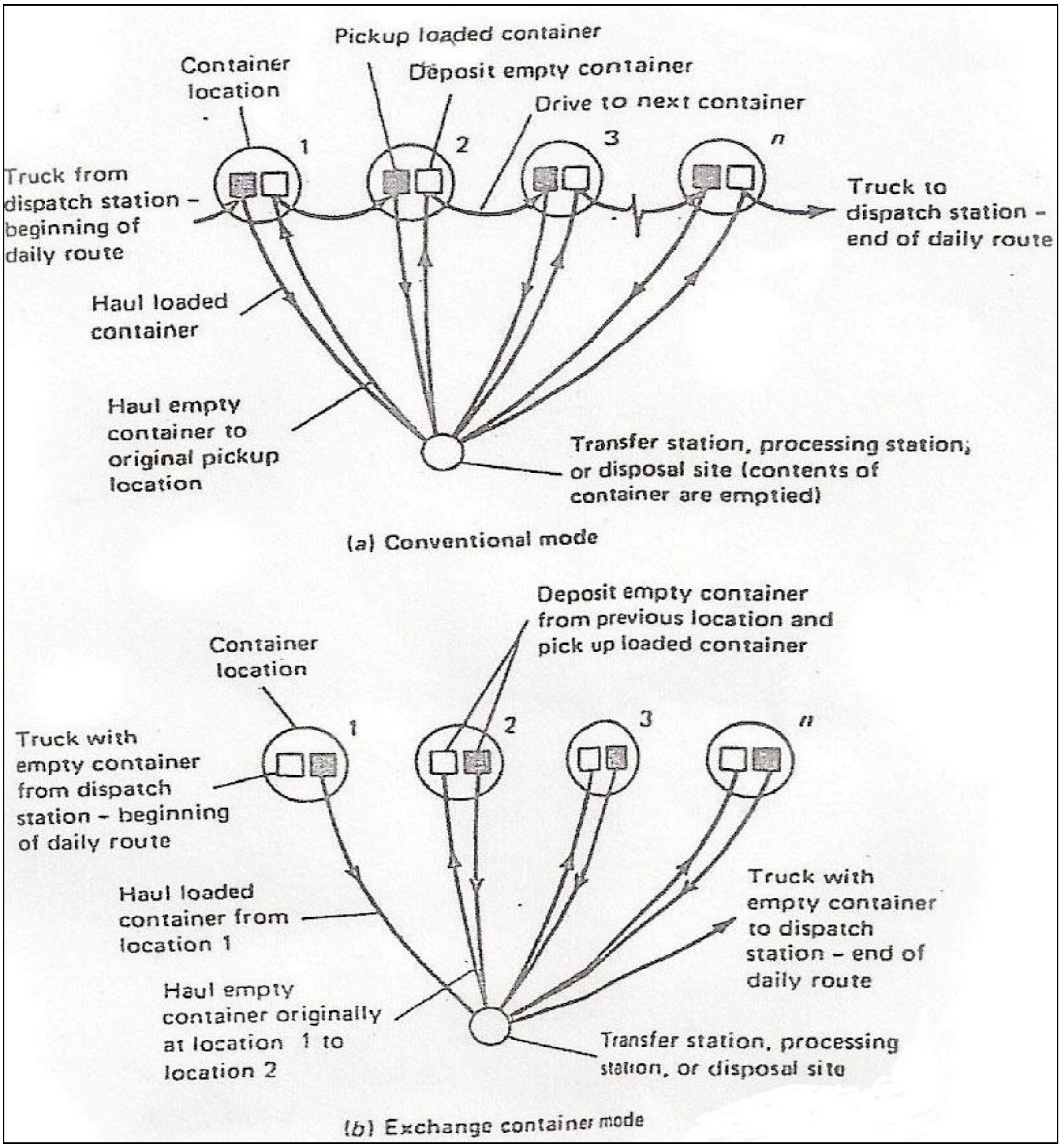

Fig 4. Sketch for waste collection haul systems: (a) Conventional mode and (b) Exchange –container mode

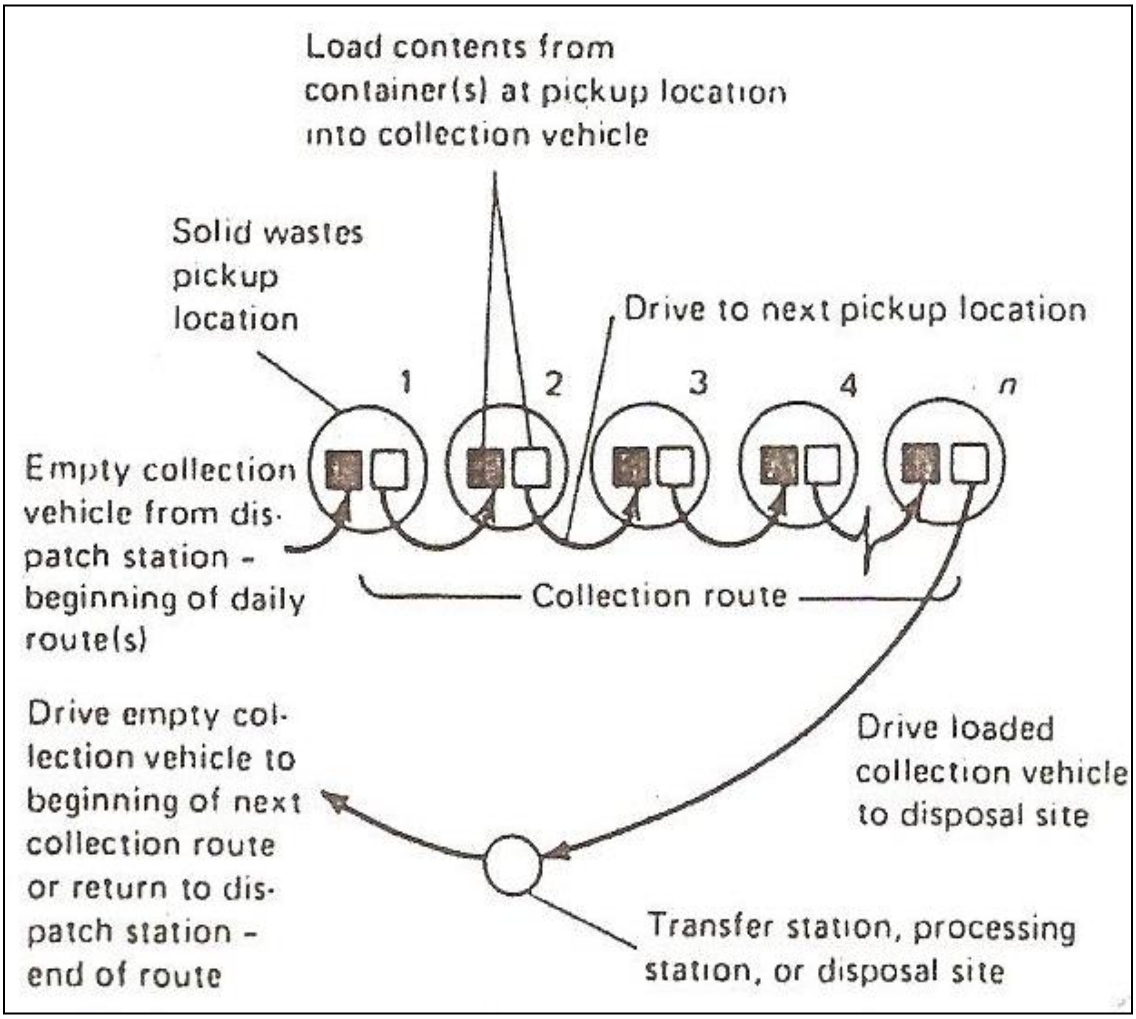

Fig.5 Schematic of operational sequence for stationary container

Analysis of collection systems

Definition of terms

The activities involved in the collection of SW can be resolved into four unit operations: pickup, haul, at-site, and off-route. **These unit operations are defined in Table 3.1**

Table (3.1) Definition of terms for the activities involved in the collection of solid wastes.

Term	Definition
Pick up (p)	
Hauled–container system P_{hcs}	The time spent picking up the loaded container, the time required to redeposit the container after its contents have been emptied, and the time spent driving to the next container.

Stationary–container system P_{scs}	**The time spent loading the collection vehicle beginning with the stopping of the vehicle point to load the content of the first container and ending when the contents of the last container to be emptied have been loaded.**
Haul (h)	
Hauled–container system h_{hcs}	**The time required to reach the disposal site, starting after the container whose contents are to be emptied has been loaded on the truck , plus the time after leaving the disposal site until the truck arrives at the location where the empty container is to be redeposited. Time spent at the disposal site is not included.**
Stationary–container system h_{scs}	**The time required to reach the disposal site, starting after the last container on the route has been emptied or the collection vehicle is filled , plus the time after leaving the disposal site until the truck arrives at the location of the first container to be emptied on the next collection route. Time spent at the disposal site is not included.**
At-site (s)	
	The time spent at the disposal site including the time spent waiting to unload as well as the time spent unloading
Off-route (w)	**All time spent on activities that are nonproductive from the point of view of the overall collection operation. Necessary off-route time includes (1) Time spent checking in and out in the morning and at the end of the day (2) Time lost due to unavoidable congestion (3) Time spent on equipment repairs and maintenance. Unnecessary off-rout time includes time spent for lunch in excess of the stated lunch periods and time spent on taking unauthorized coffee breaks, talking to friends, etc.**

Hauled–container system

The time required per trip, is equal to the sum of pick-up, at site, and haul times and given by the following equation:

$$T_{hcs} = (P_{hcs} + s + h) \qquad (1)$$

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

P_{hcs} = pick up time per trip for hauled- container system, h/trip

S = at site time per trip h/trip

h=haul time per trip h/trip

h =a+bx

a = empirical haul constant h/ trip Table (3.2)

b = empirical haul constant h/ km

x = round trip haul distance km/trip

The pick up time per trip Phcs is equal to:

Phcs= pc+ uc + dbc .... (2)

Where Phcs = pick up time per trip h/trip

Pc= time required to pickup loaded container h/trip table 3.3

ac = time required to unload (deposit) the empty container h/trip

dbc = average time spent driving between container locations h/trip (Determined locally)

The number of trips that can be made per vehicle per day with a hauled container system, including a factor to account for off-route activities, is determined using Eq. 3

N_d = [(1-W) H – (t_1 + t_2)] / (P_{hcs}+ s + a+ bx)...................................... (3)

Where N_d =number of trips per day trip/d

W= off-route factor, expressed as a fraction

H = length of work day, h/d

T_1 = time from garage to first container location, h

T_2= time from last container location to garage, h

The off-rout factor (w) in eq. 3 varies from 0.1 to 0.25 a factor of 0.15 is representative for most operations.

Assuming that the number of containers to be emptied per week is known, the time required per week can be estimated by,

Dw = Nw [Thcs + S + h]/ {(1- W) * H }

If weekly number of trips is unknown, it can be estimated as follows:

Nw = Vw /C.f

Nw = number of trips per week, trip/ wk

Vw = weekly waste generation rate , Yd^3 / wk

C = average container size carried per trip, Yd^3 / trip

f = weighted average container utilization factor

Stationary–container system

Tscs = Tscs + S + h

$Tscs = C_t . uc + (N_{pL} - 1) (dbc)$

Where,

Ct= Number of container emptied per trip, h/trip

uc= average time required to unload container, h/container

N_{pL} = Number of container pick up locations per trip,

dbc = average time spent driving between container locations, h/ location(determined locally)

The number of containers that can be emptied per collection trip is related directly to the volume of the collection vehicle and the compaction ratio that can be achieved. This number is given by:

$Ct = V_v . Z / V_c . f$

Where,

Vv = volume of collection vehicle, m^3/trip

V_c = container volume , m^3 / container

Z= compaction factor

f = weighted container utilization factor (usually 0.7).

The number of trips required per day, trips/d

$Mdc = V_d / V_v .Z$

Where,

Mdc = number of collection trips required per day, trips/d .

V_v = volume of collection vehicle, m^3 /trip

V_d = daily waste generation rate, m^3 /d

z= compaction factor

Table (3.2) Typical values for haul constant coefficients a and b in eq. 1

Speed limit km/h	Speed limit mi/h	a h/trip	b h/km	b h/mi
88	**55**	**0.016**	**0.011**	**0.018**
72	**45**	**0.022**	**0.014**	**0.022**
56	**35**	**0.034**	**0.018**	**0.029**
40	**25**	**0.050**	**0.025**	**0.040**

Table (3.3) Typical data for computing requirements for hauled and stationary –container collection systems

Vehicle	Loading method	Compaction ratio Z	Pick-up loaded container and deposit empty container h/trip (pc+uc)	Empty contents of loaded container h/container uc	At site time h/trip
Hauled-container system	**Mechanical**	**2-4 (average 2.5)**	**0.4**		**0.133**
Stationary	**Mechanical**	**2-4 (average 2.5)**		**0.05**	**0.10**

Example 1

Solid waste from a new industrial park is to be colleted in large container (drop boxes), some of which will be used in conjunction with stationary compactors. Based on traffic studies at the similar parks it is estimated that the average time to drive from the garage to the first container (t_1) and from the last container (t_2) to the garage each day will be 15 and 20 min., respectively. If the average time required to drive between containers is 6 min and the one-way distance to the disposal site is 25 km (speed limit:88 km/h) , determine the number of containers that can be emptied per day, based on 8-h work day

Solution

1. Determine the pick-up time per trip $P_{hcs}= pc+ ac + dbc$

Use : pc+ ac = 0.4 h/trip (table 4)

dbc= 0.1 h/trip (given)

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

$= 0.5$ h/trip

2. Determine the time per trip $T_{hcs}= (P_{hcs}+ s + a+ bx)$

Use : $p_{hcs} = 0.5$ **h/trip (from step 1)**

S = 0.133 (table 4)

a = 0.0166 (table 5)

b = 0.011 (table 5)

$T_{hcs} = [0.5+ 0.133 + 0.016+ 0.011 (50)]$ h/trip

$= 1.20$ h/trip

3. Determine the number of trips that can be made per day

$$N_d = [(1-W) H – (t_1 + t_2)] / (P_{hcs}+ s + a+ bx)$$

Use : W= 0.15 assumed

H = 8 h given

t 1= 0.25 h given

t 2= 0.33 h

Nd=[(1-0.15)8 (0.25+0.33)]/ (1.20) h/trip

= (6.8-0.58)/ 1.20

= 5.18 trips/d

Nd actual=5 trips/d

1. **Determine the actual length of the workday:**

5 trips=[(1-0.15)H-0.58]/1.2
H=7.74 h (essentially 8h)

Collection routes

Collection routes must be laid so both the work force and the equipments are used effectively. In general, the layout of collection routes is a trial –and error process. There is no fixed rules that can be applied to all situations. Some of the factors that should be taken into consideration when laying out routes:

1. Existing company policies and regulations such as the point of collection and frequency of collection.
2. Existing system conditions such as crew size and vehicle types
3. Waste generated at traffic-congested locations, should be collected as early in the day as possible.
4. Sources at which extremely large quantities of wastes are generated should be serviced during the first part of the day,
5. Scattered pick-up points where small quantities of solid wastes are generated should, if possible be serviced during one trip or on the same day.

Layout of Routes

The layout collection routes is a four step-process.

First, prepare location maps on a relatively large scale map of the area to be served, the following data should be plotted for each solid-waste pick-up point: location, number of containers, collection frequency.

Second, prepare data summaries. Estimate the quantity of waste generated from pick-up locations serviced each day. Where the stationary system is used, the number of pick up cycle must also be determined

Third, lay out preliminary collection routes starting from the dispatch station. A route should be laid out that connects all the pickup locations to be served during each collection day. The rout should be laid out so that the last location is nearest the disposal site.

Fourth, develop balanced routes. After the preliminary collection routes have been laid out, the haul distance for each route should be determined. In some cases it may be necessary to readjust the collection routes to balance the work load and the distance traveled. After the balance, routes have been established they should be drawn on the master map.

Collection vehicle Routing Schedule

A master schedule for each collection route should be prepared for use by the engineering department and the transportation dispatcher. A schedule for each route, on which can be found – the location and order of each pickup point to be serviced, should be prepared for the driver. In addition, a route book (register) should be maintained by each truck driver.

Example 2

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 17.7 km away.

Round trip distance X Km/trip	Total time h	Average haul Speed km/h
3.2	0.12	27
8.0	0.18	45
12.8	0.25	50
19.3	0.33	60
25.7	0.40	65
32.8	0.48	65
40.2	0.56	70

The linearization of form of haul- speed equation is

$$\frac{X}{Y} = h = a + bX$$

Number of collection vehicles needed for a community may be determined from below equation:

$$N = \frac{S * F}{X * W}$$

Where:

N = Number of collection vehicles needed.

S = Total number of customers serviced.

F = Collection frequency, number of collections per week.

X = Number of customers a single truck can service per day.

W = Number of workdays per week.

Example 3

Calculate the number of collection vehicles a community would need if it has 4000 services (customers) that are to be collected once per week during working days in a city in Iraq. (Realistically, most trucks can service only about 200 to 300 customers before the truck is full and a trip to the landfill is necessary).

Solution

1) Given:

N = Number of collection vehicles needed

S = Total number of customers serviced = 4000

F = Collection frequency, number of collections per week = 1

X = Number of customers a single truck can service per day (A single truck can service 300 customers in a single day and still have time to take the full loads to the landfill) = 300.

2) W = Number of workdays per week (The town wants to collect on Saturday, Sunday, Monday, and Tuesdays leaving Wednesdays for special projects and truck maintenance) = 4 days.

3) Thus: N = SF/XW = (4000 *1)/(300*4) = 3.3

4) The community will need four trucks.