Solid Waste Management

By

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Onsite Handling Techniques

It refers to the activities associated with the handling of solid wastes until they are placed in the containers used for their storage before collection.(***Picked up, Transfer and Placing***)

Residential

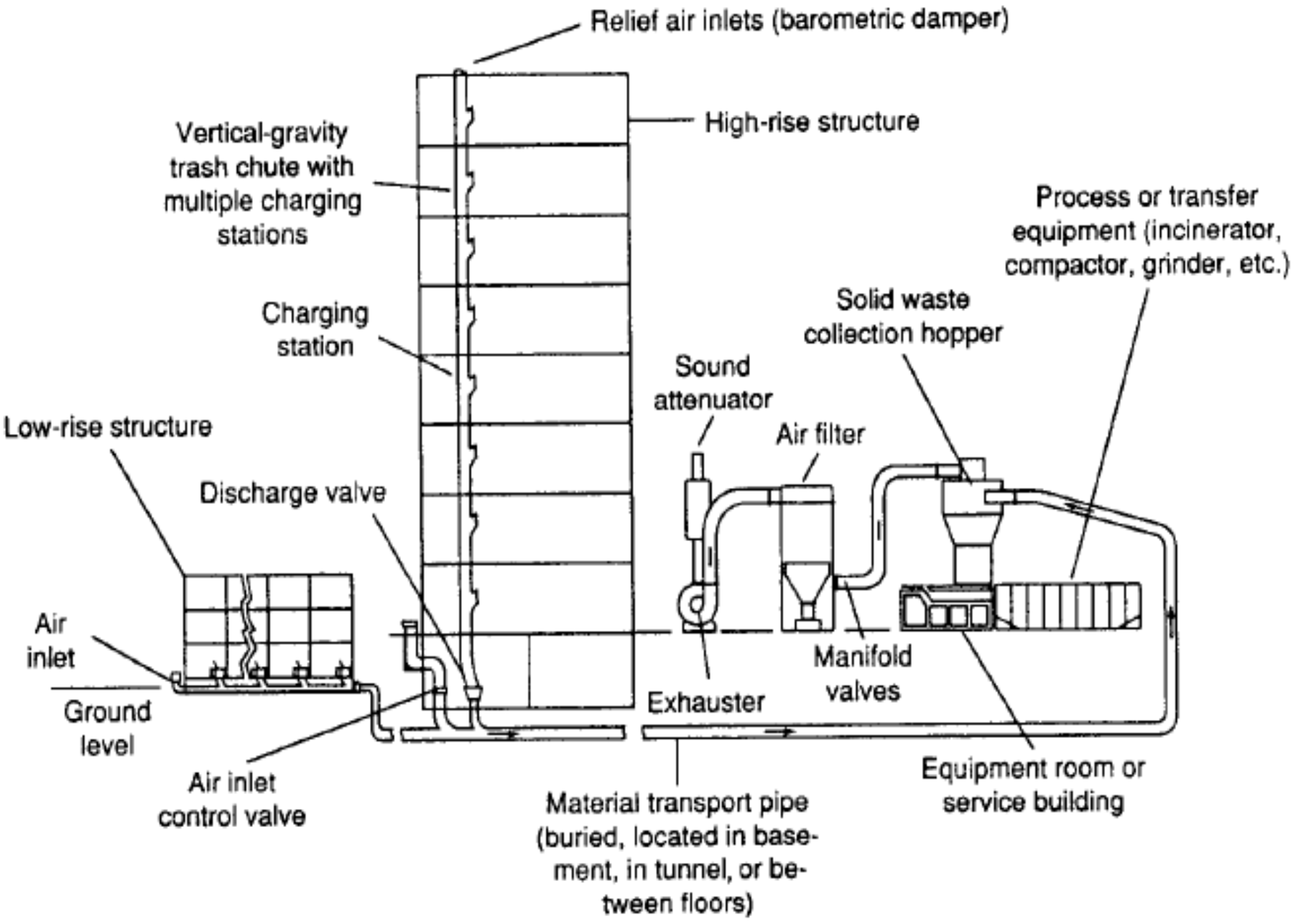
i) Residential low-rise buildings.

- Residents or tenants are responsible for placing solid wastes that are generated and accumulated at various locations in and around their dwellings in the storage containers.
- Household compactors and small-wheeled handcarts can be used as auxiliary equipments and facilities.

ii) Medium and High-Rise apartments.

- Picked up by building maintenance personnel or porters or tenants from various floors in bags and
- taken to the basement or service area,
- placed by the tenants in the specially designed chutes, with opening at each floor.

Chutes System for Individual High Rise Buildings

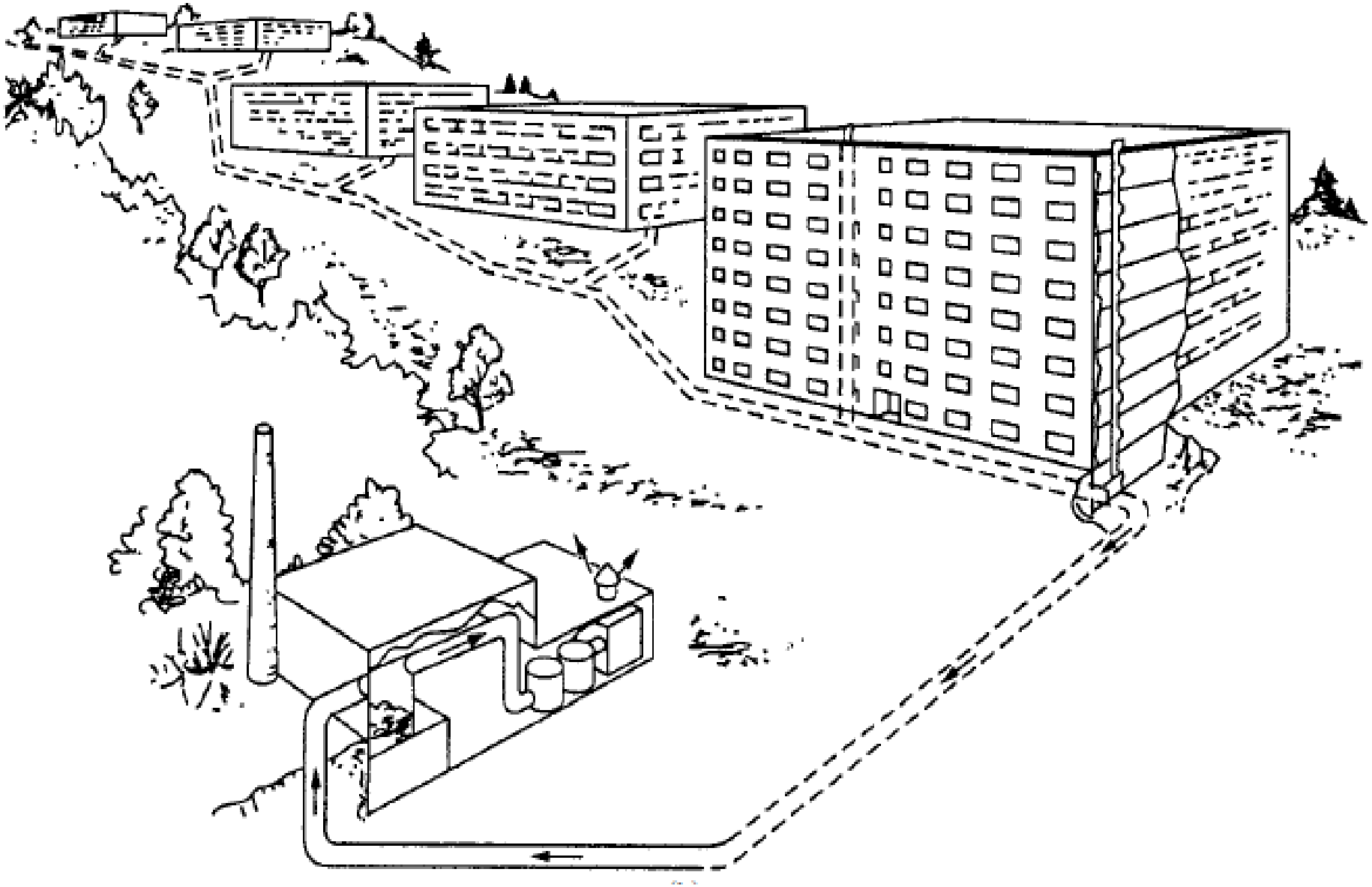


- The collection service for large apartments depends on the type of containers and processing equipment that is used.
- Large containers with and without compaction
- Contents of the containers may be emptied mechanically or Loaded containers are hauled to an off-site location (e.g., a materials recovery facility)
- Depends on size and type of container used,

Pneumatic Transport Systems

- In some developed countries (e.g. Europe), underground pneumatic transport systems have been used in conjunction with the individual apartment chutes.
- Wastes are transported from the chute discharge points to centralized processing facilities.
- Both air pressure and vacuum transport systems have been used in this application.

Chutes System with Underground Pneumatic waste Collection and Transport for Large Apartment complexes composed of Numbers of Buildings



iii) Commercial-Industrial Facilities

- Both manual and mechanical collection are used
- In large cities , to avoid traffic congestion during the day, collection is done in the late evening and early morning hours.
- For manual collection, wastes in plastic bags, cardboard boxes, and other disposable containers, are placed on the curb.
- A collection crew of 3 to 4 person with a driver is used
- Large moveable containers are used for areas where traffic congestion is not a major problem and space for storing containers is available.
- Containers that can be coupled to large stationary compactors
- Types of Containers used at high-rise apartments, depend on the size and type of container used,
- Contents are emptied
  - mechanically, or
  - Containers are hauled to an off-site location
- Mechanized collection is also accomplished with a driver & helper.

iv) Commercial and industrial buildings

Employees are responsible for placing the wastes in wheeled carts, burlap drop cloths, service elevators and conveyors etc.

v) Open areas

Owners and park management are responsible for placing the wastes in vandal proof containers.

Residential Collection Services

Low Rise and Detached Dwellings

Includes following five most common types of services

(1) Curb,

(2) Alley,

(3) Setout-setback

(4) Setout,

(5) backyard carry

- **Curb**
  - the homeowner or tenants are 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 event
  - Household compactors and small-wheeled handcarts can be used as auxiliary equipments and facilities.

- **Alley**

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

- **Set-out and Set-back**

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.

- **Set-out and Set-back**

Similar to setout-setback service, except that the homeowner is responsible for returning the containers to their storage location.

- **Backyard Carry**

Collection crew is responsible for entering the property and removing the wastes from their storage locations.

Onsite Storage

Important factors for Consideration in the onsite storage of solid waste are as followings:

i) Type of containers to be used.
ii) The containers location
iii) Public health and aesthetics and
iv) Collection method to be used.

i) Types of containers used for storage of solid wastes

- **Small containers**
  - Standardized containers

    Are specially made for solid waste collection
  - non-standardized containers

    which are not made for solid waste collection

- **Disadvantages**

  Damaged or corroded over time. Not suitable for bulky wastes

- **Medium Containers**
  - Made of plastic or galvanized metal.
  - Capacity varies from 0.7-4 m^3,
  - Used in industries & commercial setups, high rise buildings, commercial .
  - These are handled mechanically.

- **Disadvantages**
  - Damaged over time and degraded in appearance and capacity.
  - Not suitable for bulky wastes.

- **Large containers**

  - These are open top containers, made of mild steel.
  - Capacity varies from 6-60 m^3, Used in large industries, commercial setups, high rise buildings, and community and can handle bulky wastes.
  - These are handled mechanically.

Types of containers based on User

- Separate Containers

  - Small containers
  - Used for particular purposes
    e.g. industry, home

- Communal Containers

  - Relatively large containers
  - Used by community
  - Made of masonry, concrete, mild steel

- **Characteristic of good container**

  - Containment (no littering or leakage)
  - Convenient to handle
  - Environmentally sound.(Safe from winds and run off by rain and scavenging by dogs, rats and cats etc.
  - Economical
  - Accepted by public.

Collection of Solid Waste

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

- **Types of collection system**

i) Hauled Container System

- Loaded containers are picked up & empty containers are brought back by the collection vehicles.
- Hauled container systems are useful for removal of wastes from the sources where the rate of generation rate is high because relatively large containers are used.

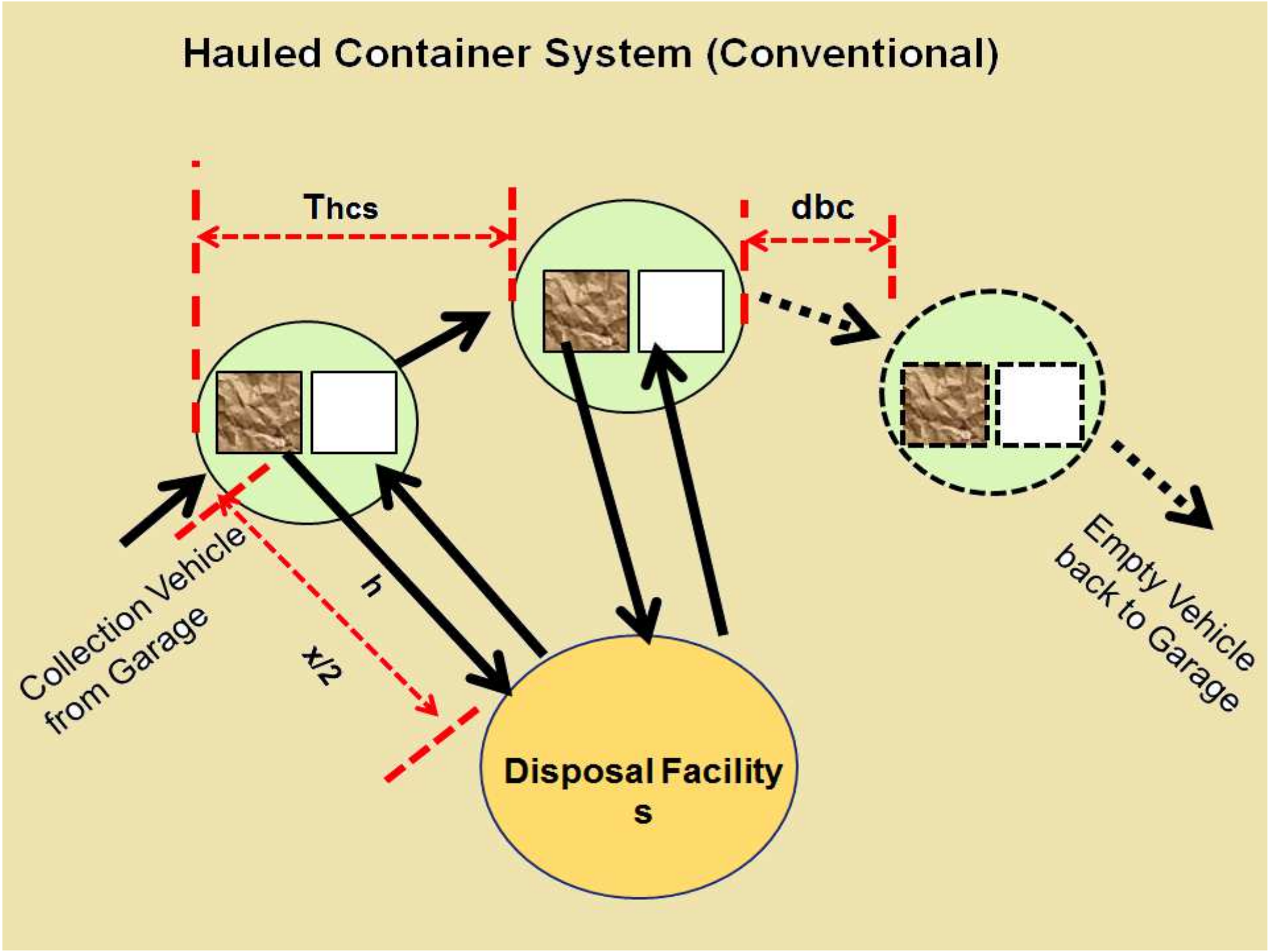
Types of Hauled Container System

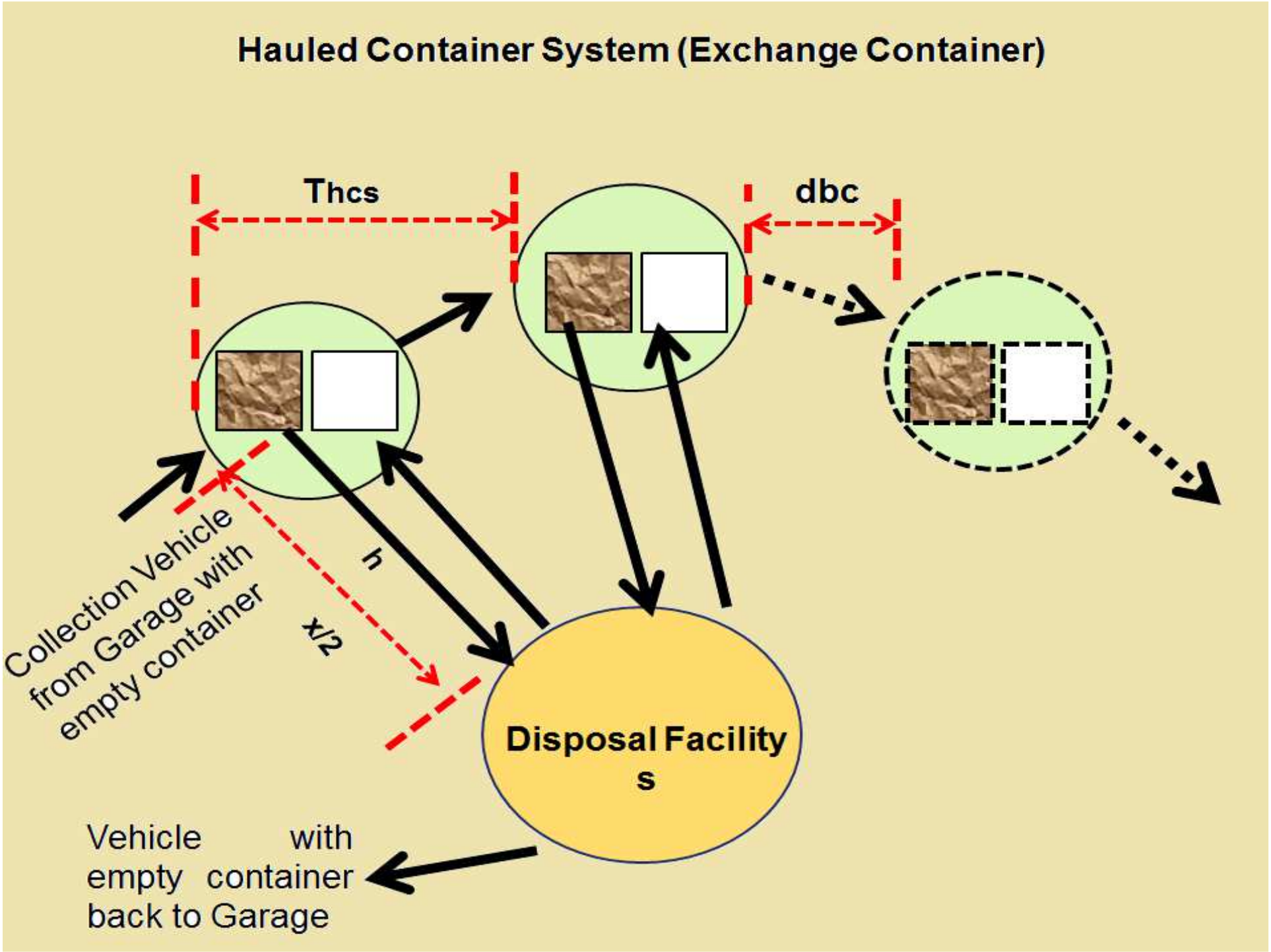
a) ***In conventional hauled container system***

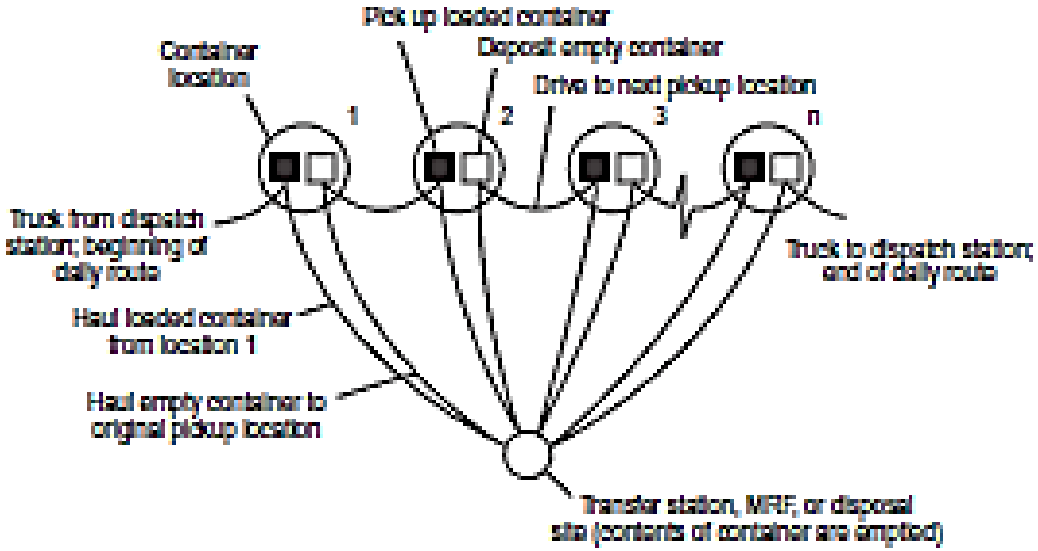
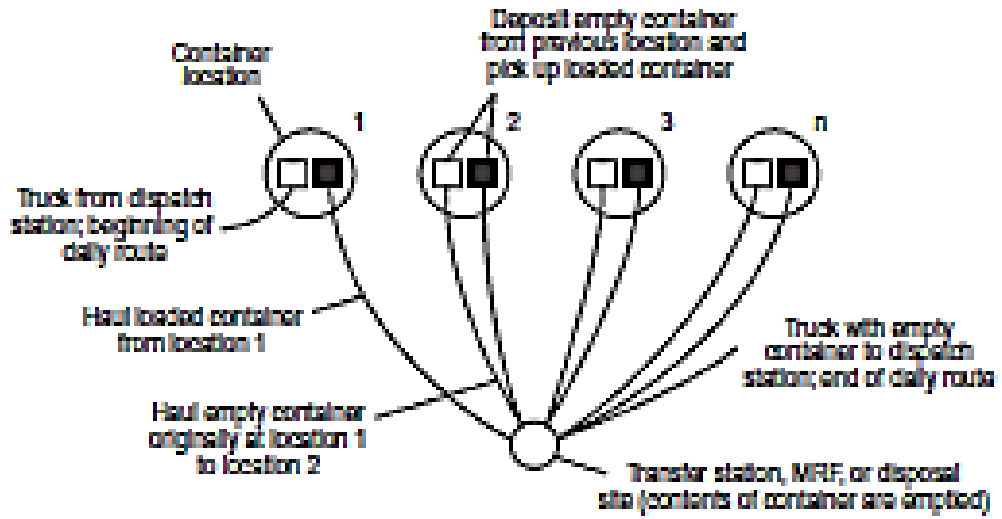
Vehicle takes the loaded containers to the disposal or transfer station.

b) ***In exchanged container (hauled) system***,

Collection vehicle brings an empty container and replace it with loaded/filled container


Hauled Container System (Conventional)
Thcs
dbc
Collection Vehicle from Garage
h
x/2
Disposal Facility s
Empty Vehicle back to Garage


Hauled Container System (Exchange Container)
Thcs
dbc
Collection Vehicle from Garage with empty container
h
x/2
Disposal Facility
s
Vehicle with empty container back to Garage

Schematic of operational sequence	System description
(a) Hauled container system (conventional mode) 	Containers used for the storage of wastes are hauled to an MRF, transfer station, or disposal site, emptied, and returned to their original location.
(b) Hauled container system (exchange container mode) 	Containers used for the storage of wastes are hauled to an MRF, transfer station, or disposal site, emptied, and returned to a different location in the exchange mode of operation. The exchange mode works best when the containers are of a similar size. In the exchange mode, the driver must begin the collection route with an empty container on the vehicle to be deposited at the first collection site.

$$Thcs = \frac{(pc + Uc + h + s + dbc)}{(1-w)}$$

w = Off rout factor i.e. factor taking care of time spent on off rout activities by crew. Recommended values is 15%

Thcs	**=**	**Total hauled container time/Trip (hours)**
pc	=	Pick up of container time (hours)
Uc	=	Unloading time of container (hours)
h	=	Hauled time for round trip i.e. time for going to and coming back from disposal site (hours)
s	=	Time at disposal site (hours)
dbc	=	Time between container
x	=	Round trip distance to disposal site
h	=	a + bx (hours/trip)
a	=	Hours/trip (A constant taking care of starting and stopping of vehicles
b	=	Constant depending on speed of vehicle

Definitions

Pickup

Definition of Pickup time depends upon the type of collection system

- **For conventional HCS**, pickup refers to the time spent driving to the next container after depositing the empty container, the time spent in picking up the loaded container and time required to redeposit the container after its contents have been emptied.
- **For exchange container system**, pickup time includes the time required to pick up a loaded container and to redeposit the empty container at the next location after its contents have been emptied.
- **For Stationary Container system**, it refers to time spent loading the collection vehicle, beginning with the stopping of the vehicle prior to loading the contents of the container and ending when the contents of the last container to be emptied have been loaded.

Haul

Definition of haul depends upon the type of collection system

- For hauled container system, haul represents the time required to reach the disposal site, after a 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 re-deposited. It does not include the any time spent at the disposal site
- For stationary container system, haul refers to the time required to reach the disposal site, starting after the last container on the rout has been emptied or the collection vehicle of filled, plus the time after leaving the disposal site until truck arrives at the location the first container to be emptied on the next collection rout. It does not include time spent at the disposal site.

- **At Site (s)**

  The unit operation at-site (s) refers to the time spent at the disposal site and includes the time spent waiting to unload as well as the time spent unloading

- **Off-Rout (w)**

  - The unit operation off-rout (w) includes all time spent on activities that are nonproductive from the point of view of the overall collection operation
  - It may be divided into two categories
    - Necessary (*check in & out, driving time to 1st pick up point & from the approx. location of the last pick up point to dispatch station, congestions, repairs of equipment*)
    - Un-necessary (*time spent as excess lunch time, un-authorize tea breaks, talking to friends*
  - Both are considered together because they must be distributed equally over entire operation

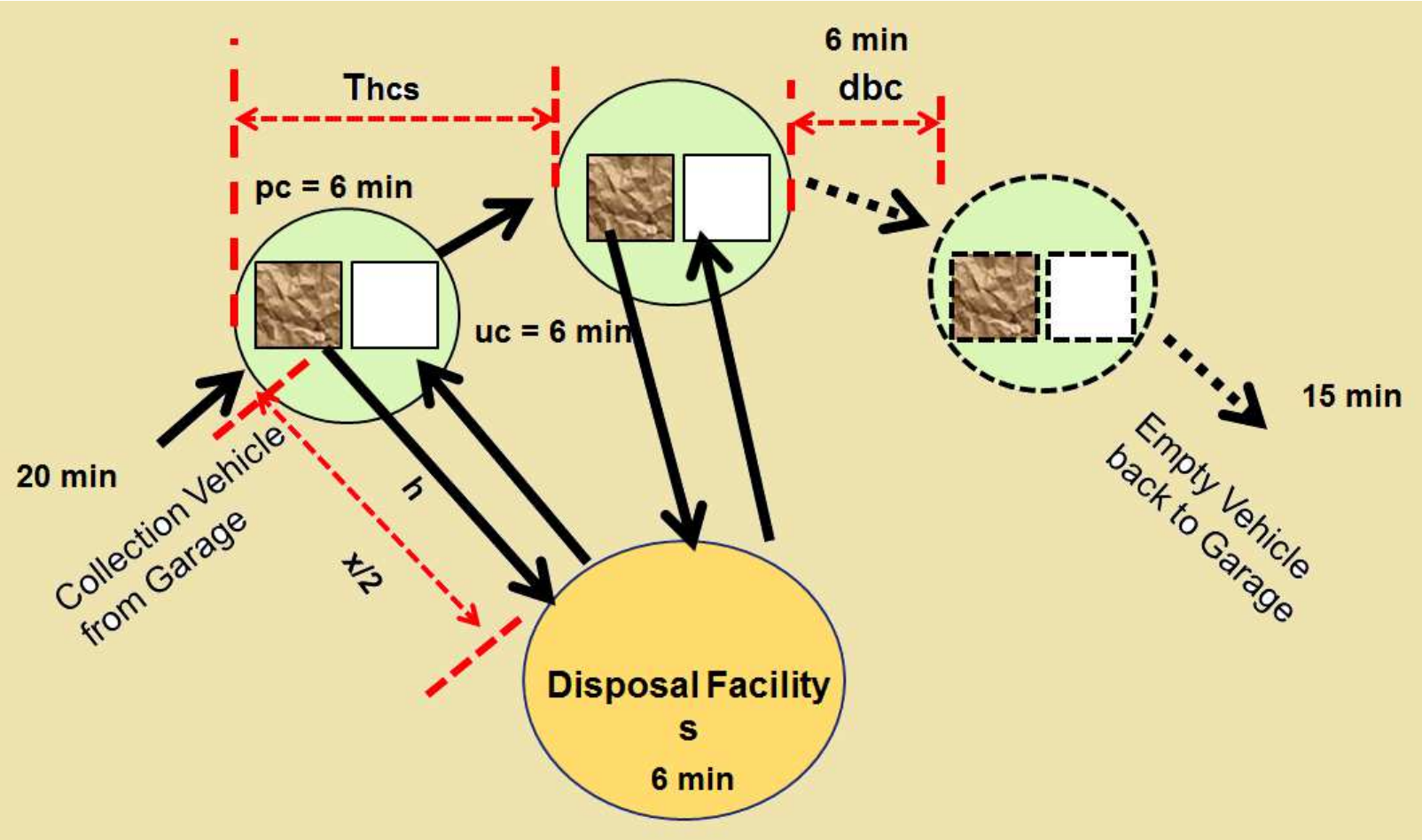
Container Utilization Factor (f)

Defined as the fraction of the container volume occupied by Solid Waste. Vary with size of the container

Problem

Because of the difference of the opinion among the city staff members, you have been retained as an outside consultant to evaluate the collection operation of the City. The basic question centers around the amount the time spent on off-rout activities by the collectors. The collectors say that they spend less than 15 percent of each 8-hour workday on off-rout activities; management claims that the amount of time spent us more than 15 percent. You are given the following information that has been verified by both the collectors and management.

1	**A hauled container system , without container exchange is used**		
2	The average time spent driving from corporation yard to the first container		20 min
3	Ave.Pick up time per container	pc	6 min
4	Ave. time taken to drive b/w containers	dbc	6 min
5	Ave. time required to empty container	uc	6 min
6	Ave.round trip distance to disposal site &	x	10 mi /trip
	haul equation is (a=0.004 h/trip & b = 0.02 h/mi	h =	(a + bx)
7	Time to redeposit the container after it has been emptied	s	6 min
8	Ave. time spent driving from last container to corporation yard & no off rout activities occur		15 min
9	No. of container emptied		10 per day



$$Thcs = \frac{(pc + Uc + h + s + dbc)}{(1-w)}$$

w = Off rout factor i.e. factor taking care of time spent on off rout activities by crew. Recommended values is 15%

Solution

Effective time	=	8(60)-(15+20)	
	=	445 mins	
h	=	a+bx	
	=	0.004 + 0.02X10	= 12.24 min/trip

$$Thcs = \frac{(pc + Uc + h + s + dbc)}{(1-w)}$$

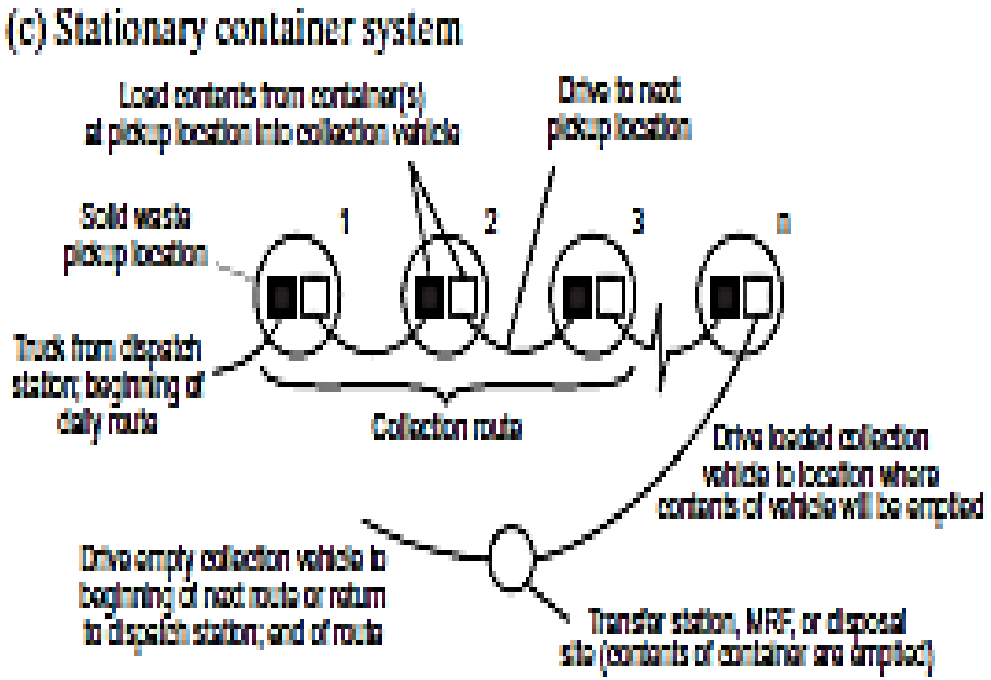
Container served = 10 Nos
No. of dbc = 09

$$Thcs = \frac{10(pc + Uc + h + s) + 9\,dbc}{(1-w)}$$

445(1-w)	=	10(6+6+6+12.24) + 9(6)	
1-w	=	0.8008	
w	=	0.199	
	=	19.9 % > 15%	

Thcs	**=**	**Total hauled container time/Trip (hours)**	
pc	=	Pick up of container time (hours)	6 min
Uc	=	Unloading time of container (hours)	6 min
h	=	Hauled time for round trip i.e. time for going to and coming back from disposal site (hours)	
s	=	Time at disposal site (hours)	6 min
dbc	=	Time between container	6 min
x	=	Round trip distance to disposal site	10 mile/trip
h	=	a + bx (hours/trip)	
a	=	Hours/trip (A constant taking care of starting and stopping of vehicles	0.004 h/trip
b	=	Constant depending on speed of vehicle	0.02 h/trip
		Total trip	10
		Total time/day	8 h

Stationary Container System



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. The collection vehicle is driven from pickup location to pickup location until it is loaded fully.

$$Tscs = \frac{(Pscs + s + a + bx)}{(1-w)}$$

- The only difference between Thcs & Tscs is Pick up time.
- For Stationary Container System pick up time is

$Pscs = C_t (Uc) + (n_p - 1) (dbc)$ where

C_t = number of container emptied per trip, container / trip

Uc = Ave. unloading time per container for SCS, h/container

np = Number of container pick up locations, locations/trip

dbc = Ave. time spent driving b/w containers locations, h/location

Systems with Manually Loaded Collection Vehicles.

- Generally used for collection of
  - Residential source-separated wastes
  - Commingled wastes and litter
  - Used in residential areas where the quantity of waste at each location is small and the loading time is short.
  - Useful for residential collection because many individual pickup points are inaccessible to mechanized mechanically loaded collection vehicles.
- Special attention must be given to the design of the collection vehicle intended for use with a single collector.
- A side-loaded compactor, equipped with stand-up right-hand drive, is best suited for curb and alley collection.

A side-loading vehicle, equipped with a right-hand stand-up drive mechanism

The rear loaded type of collection vehicle is commonly used with two- and three-person crews

$$tp = 0.72 + 0.18\,Cn + 0.014\,(PRH)$$

Where

tp	=	Ave. pick up time per pickup location collector- min/location
PRH	=	Rear off house pickup locations
		percent area of house i.e extra time taken for service form backyard

Problem

A Private Solid waste Collector wishes to locate a disposal site near a commercial area. The collector would like to use hauled container system but fears that the haul costs might be prohibitive, What is the maximum distance away from the commercial area that the disposal site can be located so that the weekly costs of the hauled container system do not exceed those of a stationary container system?. Assume that one collector-driver will be used with each system and that the following data are applicable.

1. Hauled container System

Quantity of Solid Wastes		=	300	yd^3/wk
Container size		=	8	yd^3/trip
Container utilization factor		=	0.67	
Container Pick up time	pc	=	0.033	h/trip
Container unloading time	uc	=	0.033	h/trip
At site time	s	=	0.053	h/trip
Overhead costs		=	$400	/wk
Operational Costs		=	$15	/h of operation

2. Stationary Container System

Quantity of Solid Waste		=	300	yd^3/wk
Container size		=	8	yd^3/trip
Container utilization factor		=	0.67	
Collection Vehicle Capacity		=	30	yd^3/trip
Collection Vehicle Compaction ratio		=	2	
Container unloading time	uc	=	0.05	h/container
Overhead costs		=	$750	/wk
Operational costs		=	$15	h/trip
At-site time		=	0.1	h/trip

3. Location Characteristics

a) Average distance b/w container location = 0.1 mile

b) ***Constants for estimating driving time b/w container locations for hauled container system***

a’	=	0.06 h/collection and
b’	=	0.067 h/mile

c) Constants for estimating driving time b/w container locations for Stationary container system

a’	=	0.06 h/collection and
b’	=	0.067 h/mile

d) Constants for estimating haul time

a	=	0.022 h/trip
b	=	0.022 h/mi

Solution:

$$Thcs = \frac{(pc + Uc + h + s + dbc)}{(1-w)}$$

w = Off rout factor i.e. factor taking care of time spent on off rout activities by crew. Recommended values is 15%

dbc = a' + b'x = 0.06 + 0.067x0.1 = 0.0667

h = a + bx = 0.022 + 0.022 x

No. of containers = $\frac{300}{(8x0.67)}$ = 56 trips/week

Total Costs/week = Overhead Costs + Operational Costs

Operational Costs = No.of trip per week X time per trip X Unit cost

$$Thcs = \frac{(0.033 + 0.033 + 0.022 + 0.022\,x + 0.053 + 0.0}{(1-0.15)} = 0.24435 + 0.029\,x$$

Yhcs = 400 + 56 (0.24435 + 0.029 x) 15

Yhcs = 605.254 + 21-756 x ----------(1)

Stationary Container System

Quantity of waste	=	300 yd^3 /trip
Collection Vehicle capacity	=	30 yd^3/trip
Compaction ratio	=	2
Trip/week	=	$\frac{300}{30x2}$
	=	5
Total Costs/week	=	Overhead Costs + Operational Costs

Operational Costs = No.of trip per week X time per trip X Unit cost

Yscs = $750 + $ 15 X Tscs X No. of trips

$$\textbf{Tscs} = \frac{\textbf{(Pscs + h + s)}}{\textbf{(1-w)}}$$

$$\textbf{Tscs} = \frac{\textbf{(Pscs + s + a + bx)}}{\textbf{(1-w)}}$$

Pscs = Cn X Uc + (np – 1) dbc

Cn = 56

Np = 56

dbc = 0.06 + 0.067 x 0.1 = 0.0667

Pscs = 56 X 0.05 + (56-1) 0.0667 = 6.4685

$$\textbf{Tscs} = \frac{\textbf{(Pscs + h + s)}}{\textbf{(1-w)}}$$

$$\textbf{Tscs} = \frac{\textbf{(Pscs + s + a + bx)}}{\textbf{(1-w)}}$$

$$= \frac{\textbf{6.4685 + 0.1 + 0.22 + 0.022x}}{(1\text{-}0.15)}$$

Tscs = 7.753 +0.02588x

Yscs = 750 + 15 (7.753 + 0.02588 x)5

Yscs = 1331.475 + 1.94 x ---------- (2)

Equating both equations (1) & (2)

x = 13.4 Km

Problem

An agency responsible for the collection of solid wastes presently allows two container per service, picked up a the backyard. Consideration is being given to limiting backyard service to one container only; the remaining services would be allowed two container two containers at curbside. ***About 10 % of all services would be expected to ask for the backyard service.*** How many additional containers can be collected per day?. ***At present there are 300 collection stops per day.***

Solution

Present pickup locations = 300

Container at each site to be picked up form backyard = 2

[Rear off house pickup locations]

Tp (time spent/location) = 0.72 + 0.18 Cn + 0.014 (PRH)

= 0.72 + 0.18 (2) + 0.014 (100)

= 2.48 collector-minutes

Total time for 300 locations = 300 x 2.48 = 744 collector - mins

New System

Let total no. of pickup locations in new system = Np

Locations with curbside service = 90% = 0.9 Np

Locations with backyard service = 10% = 0.1 Np

Container per location in curbside service = 2.0

Container per location in backyard service = 1.0

Tp (time spent/location) = Time spent at curbside Service + backyard

Tp (time spen) = 0.72 + 0.18 Cn + 0.014 (PRH)

744 = 0.9Np[0.72 + 0.18 (2) + 0.014 (0)] +

0.1Np[0.72 + 0.18 x 1 + 0.014 (100)

= 0.972 Np + 0.23 Np

Np = 619

Container collected = 619 x 0.9 + 619 x 0.1

= 1176

Present collection = 300 x 2 = 600 Nos.

Additional collection = 1176 – 600 = 576

Problem

Your friend and her friend are looking for some part time work. You live in a small rural community and does not receive regular waste collection service. Your friend thinks it would be a good idea to provide waste collection service using ¾ ton four wheel drive pickup truck. There are 30 houses, and each one uses two 32 gals containers. All the houses would receive backyard service once per week. The haul constants are 0.08 h/ trip and 0,025 h/mi. Assume that at-site time is equal to 0.5 h. The roud trip haul distance to the disposal site is 32 miles. The size of the pickup truck bed is 6 x 8 x 3 feet. Assuming that your friend can devote 10 h/wk to this project, can they do it?.

No of houses /pick up locations	=	30
Container per house	=	02
Size of container	=	32 gal = 4.5 ft3
Size of vehicle (6 x 8 x 3 feet)	=	144 ft3
x	=	32 miles
a	=	0.08 h/trip
b	=	0.025 h/mile
s	=	0.5 h
w	=	0.15
Collection frequency	=	1 /week

h = ax + b

h = 0.08 + 0.025 (32) = 0.88 h/trip

tp = 0.72 + 0.18 Cn + 0.014 (PRH) [Rear off house pickup locations]

= 0.72 + 0.18 (2) + 0.014 (100)

= 2.48 collector-minutes

Trip/wk = $\frac{144}{2x4.5}$

= 16

Pscs = $\frac{Np \times tp}{60 \times n}$

= $\frac{16 \times 2.48}{60 \times 2}$

= 0.33 hours

Tscs = $\frac{Pscs + h + s}{(1-w)}$

= $\frac{0.33 + 0.88 + 0.5}{(1 - 0.15))}$

= 2.01 hours/week < 10 h/week

(can do the job)

Problem Design a solid waste collection system to service a residential area with 1000 single-family dwellings. Assume that a two-person collection crew will be used and that the following data are applicable

Average No. of residents per service	**=**	**3.5**
SWM generation rate per capita	=	1.0 kg/capita/day
Density of Solid wastes (at container)	=	100 kg/m^3
Container per service	=	2
Capacity of each container	=	128 liters
Type of service &	=	50% backyard & 50% Alley
Collection frequency	=	Once/week
Collection vehicle	=	Compactor with compaction ratio of 2
Round trip haul distance	=	15 km
Length of work day	=	8 hours
Trip per day	=	2
w	=	0.15
a = 0.016 h/trip		b = 0.018 km/h
s =0.1 h/trip,		No. of collectors = 2

Solution:

tp = 0.72 + 0.18 Cn + 0.014 (PRH) [Rear off house pickup locations]

= 0.72 + 0.18 (2) + 0.014 (50)

= 1.76 collector-minutes

Time per day = 8 hours

Trip /day = 02

Ave.time per trip = 8/2 = 4 hours

$$Tscs = \frac{Pscs + (ax + b) + s}{(1-w)}$$

$$4 = \frac{Pscs + [0.016x15 + 0.88] + 0.1}{(1 - 0.15)}$$

Pscs = 3.01 h

$$Np = \frac{60x\ Pscsxn}{tp}$$

$$Np = \frac{60 \times 3.01 \times 2}{1.76}$$

= 205 location /trip

Trips = 1000 / 205 = approx 5 trips

Total location	=	205	
No of person/location	=	3.5	
SWM GR =	1 kg/person/day		
SWM / week	=	3.5 x1 x205 x 7	
	=	5022.5 kg	
Volume	=	mass/density of SW	
	=	5022.5 / 100	= 50 m^3
Vehicle required	=	50/2	= 25 m^3
Days required	=	5/2	= 2.5 days

Collection Routes

Important factor for laying down collection routes include:

i) Consider and identify existing policies and regulation (e.g. point of collection and frequency.

ii) Consider existing system conditions(e.g.Crew size and vehicle types etc.

iii) Wherever possible, routes should be laid out so that they begin and end near arterial streets, using topographical and physical barriers as rout boundaries.

iv) In hilly areas routes should start at top the grade and proceed downhill as the vehicle becomes loaded.

v) Routes should be laid out so that the last container to be collected on the rout is located nearest to the disposal site.

vi) Wastes generated at traffic-congested locations should be collected as early in the morning as possible.

vii) Sources at which extremely large quantities of wastes are generated should be served during the first part of the day.

viii) Scattered pick up points with small quantities of solid wastes and same frequency collection should possibly be serviced during one trip or on the same day.

Layout of Collection Routes

The four general steps involved in include:

1. Preparation of location maps showing pertinent data and information concerning the waste generation sources
2. Data analysis and, as required, preparation of information summary tables
3. Preliminary layout of routes
4. Evaluation of the preliminary routes and the development of balanced routes by successive trials

- Some form of a ***Geographic Information System*** (GIS) is now used to identify each customer's location.
- A variety of other complimentary programs have also been coupled to the GIS to both optimize the collection process and to improve the service provided.

- Balanced routes prepared in the office are given to collector-drivers who implement them in the field.
- Based on the field experience of the collector-driver, each route is modified to account for specific local conditions, and information on the new route is entered into a database.
- In large municipalities, route supervisors are responsible for the preparation of collection routes.
- In most cases, the routes are based on the operating experience of the route supervisor, gained over a period of years working in the same section of the city.

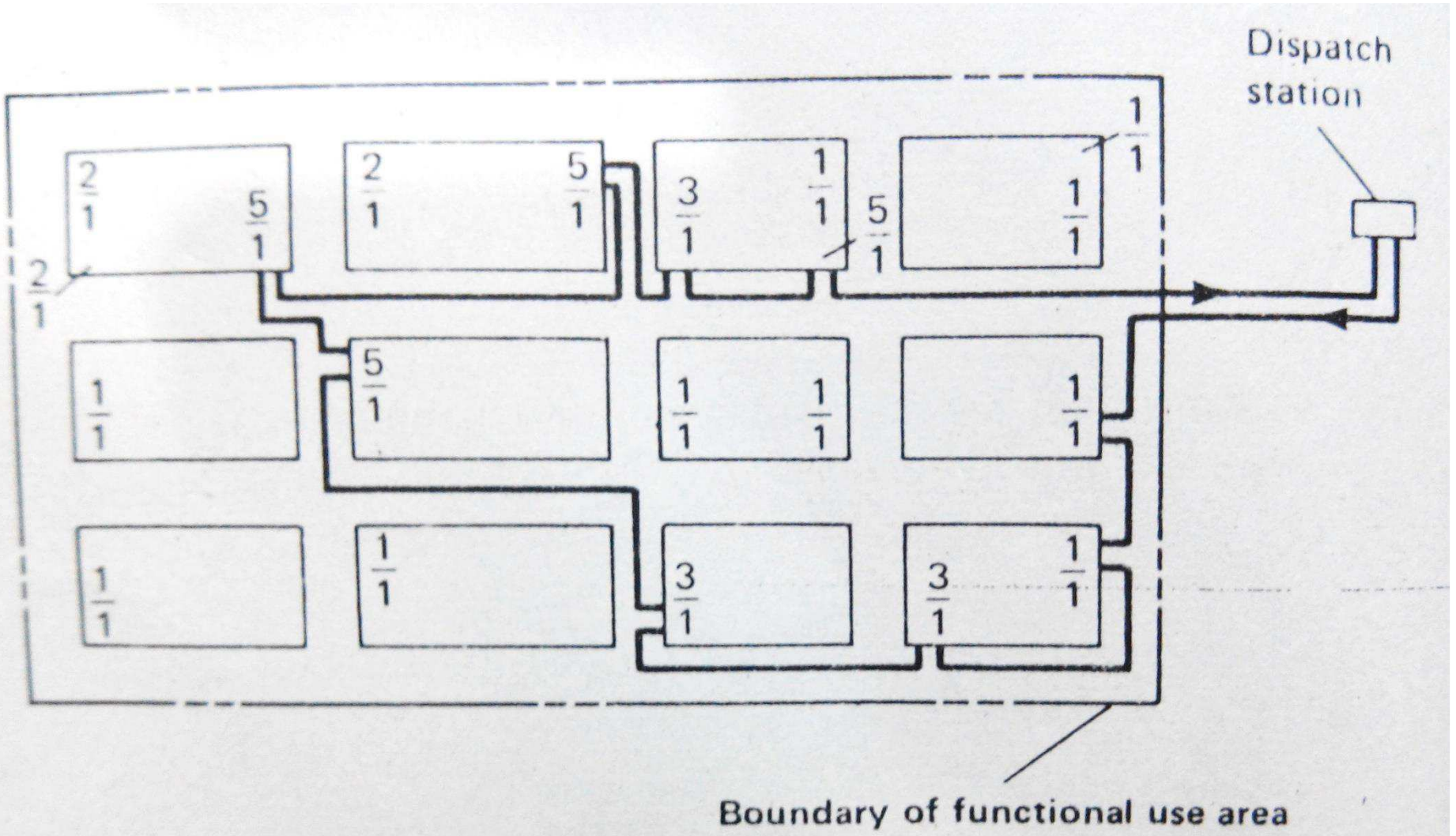
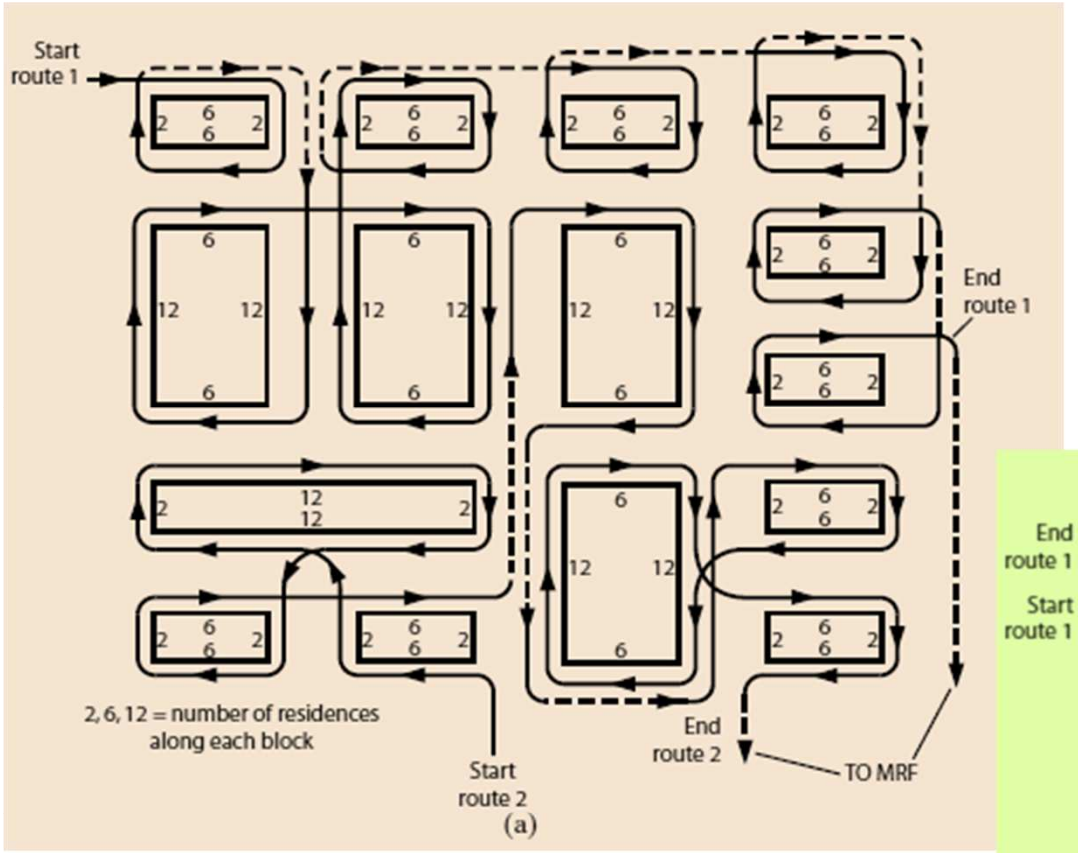
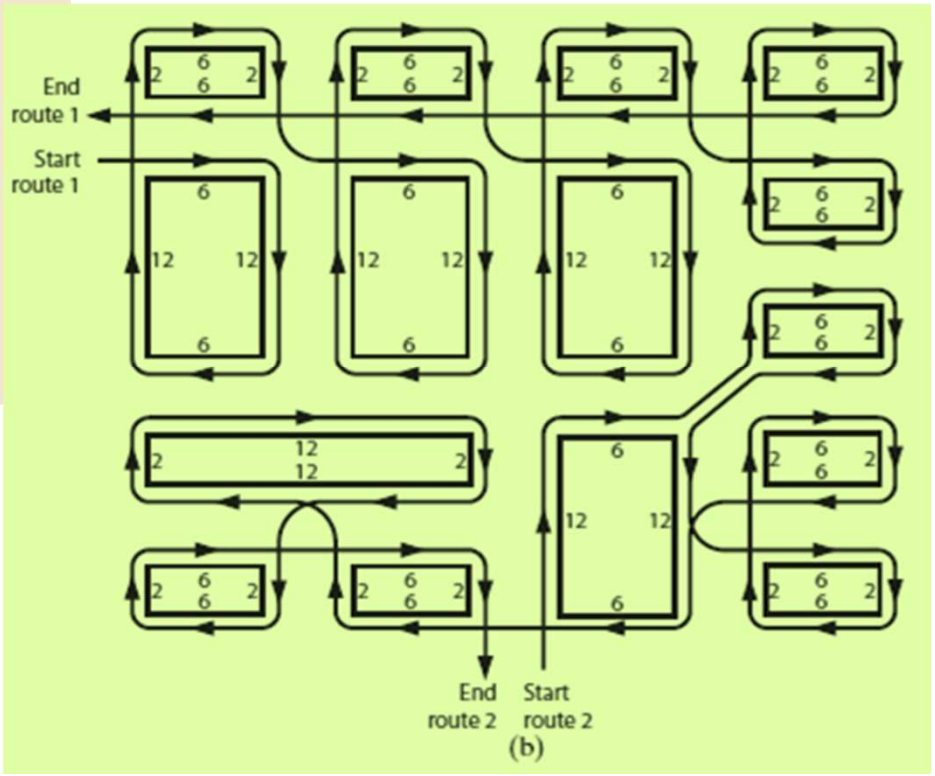


FIG. 6-19 Plan of a typical functional use area.



(a) Route layout with overlap shown by the dotted lines.

The effectiveness of the collection routes can be assessed by the amount of route overlap.



(b) Route layout without overlap.