RESOURCE ALLOCATION FOR SOLID WASTE COLLECTION AND TRANSPORTATION - Norms & Route Planning (Part - 2)

by

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Abstract

A study has been performed in order to allocate resources for collection and transportation of solid waste. All elements of route balancing and micro routing, which are functions of route planning have been analyzed.

The total time in the collection cycle per trip has been investigated taking into consideration the Havelock town area. Thereby the average time for each aspect and the optimum crew size has been calculated. The optimum number of trailers per tractor and skip bins per skip hoist has also been investigated. Here 1278 households have been investigated and it has been found that the number of residents per house is 5.8. Further, it has been found that the residential per capita waste generations varies according to the income group and that the low income per capita waste generation is 0.49 kg / per day and the high income per capita waste generation is 0. 64 kg/day. The average per capita residential collection has been found to be 0.54 kg.

A model has been developed to calculate the feasible number of collection points per vehicle per shift, for any semi residential area in order to optimize the capacity of waste transportation vehicle. The norms for road sweeping, road brushing and poster removal by machine have been developed and is also presented herein.

Introduction

In order to optimize resources and maximize efficiency the collection route has to be determined, so that the amount of refuse collected by each vehicle, in a single trip is approximately equal to its designed capacity. Further the collection vehicles should take the shortest possible time to travel from one collection point to another. It should not go through the same route twice for one trip, especially for roads with small widths as collection from both sides could be done at once. However for roads with large width, the vehicle may have to travel along both sides of the road. The refuse collection routes could be planned with the careful consideration of the traffic condition and the volume of garbage collection, in each Municipal District and Ward. For heavy traffic areas, collection during the night also could be considered. Therefore it could be seen that, it is imperative that a careful study on route planning be performed prior to scheduling of resources.

In this paper a study on route planning in semi residential areas of the Colombo Municipal Council has been presented. Here a model has been developed to calculate the number of residential to commercial premises in semi residential areas that must be covered, in order to bring the garbage collection vehicle to optimum capacity. In addition norms for other solid waste management activities such as sweeping and brushing of pavements, removal of posters etc., have been presented.

2. Procedure for Route Planning

Route planning basically could be considered as a function of route balancing and micro routing.

Route balancing is the process of determining the optimum service that covers a day's work and dividing the day's collection task among the machinery and human resources equally. Route balancing should be planned by considering the, number of residential and non- residential premises to be collected by each vehicle per trip. This depend on the,

a. Design load of the vehicles(Gamage & De Costa, Part -1)

b. Collection efficiency (Gamage & De Costa, Part - 1)

c. Frequency of collection per week (Gamage & De Costa, 1999)

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d. Waste generation rate (Gamage & DeCosta, 1999) and discussed herein.

e. No. of workers per gang (Gamage & DeCosta, 1999) and discussed herein

f. Working hours

g. Number of trips per day

Working hours could be considered as variable depending on the garbage volume to be removed and available machinery and manpower. However it is normally taken as 8 hours per day. The number of trips per day mainly depends on the distance to the disposal site and the traffic congestion.

Micro routing is the assignment of the collection routes to particular disposal sites, with optimum use of resources, minimizing the total cost. The ultimate result of the optimum plan should be the minimum round trip haul time for each route, taking into account the queuing time at the disposal site. Micro route planning depends on,

a. Location and distribution of Municipal Ward
b. Location of the disposal sites
c. Type of road network - Road widths, One way streets etc.
d. Traffic congestion, peak times & duration
e. Accessible roads & non accessible roads

All the above factors directly deal with route planning and they are discussed herein.

In addition to the above the following could be considered to be some Heuristic route planning rules.

1. Routes should not be fragmented or overlapped. Each route should consist of street segments of the same ward.
2. Commencement point of the route must be close to the ward office/workers depot.
3. Roads with heavy traffic should be avoided during the peak time.
4. Sending a back up vehicle should be avoided as much as possible.
5. Ending point of the route must be close to the disposal sites.
6. Routes should be generally planned with left turns wherever possible.

3. Study location

The Havelock town municipal ward has been selected for the study as this ward is considered to be a representative semi residential area of Colombo. Fig - 1 indicates the road net work of the Havelock Town ward. Table - 1 indicates some characteristics of the Havelock Town ward. Here the weight of the collected garbage at each premise was measured 3 consecutive times and the averages are given. This Table covers 50% of the total estimated population in 1996 in the Havelock Town ward.

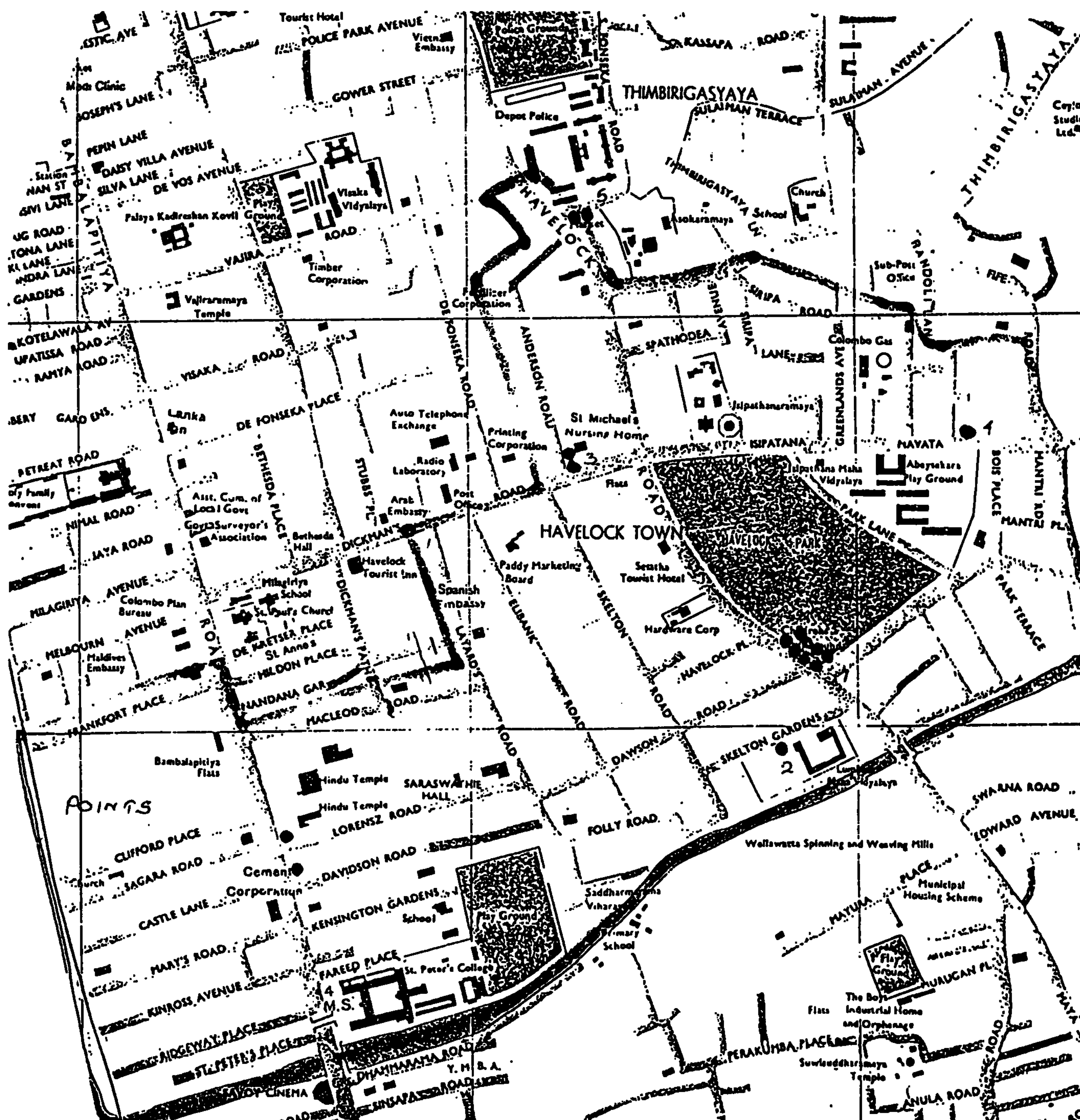

Fig -1 Road Net work of Havelock Town

Table - 1 Characteristics of Havelock Town Ward Excluding Galle Road & Havelock Road

Sample Size - 50%

Street	No of Houses	Length (km)	Width (m)	Length of Side drain (m)	Population	Weight of Garbage/2days (kg)	per capita collection (kg)
Amarasekara Road	29	0.5	12.5	1100	128	176	0.69
Ambaghawatte	6	0.1	5.5	-	33	32	0.48
Anderson Road	21	0.3	12.5	600	104	129	0.62
Bois Place	10	0.2	5.2	200	49	68	0.69
Castle Lane	40	0.4	4.8	750	394	468	0.59
Udyanapura	104	0.5	7.1	425	486	476	0.49
Clifford Place	34	0.4	7.6	150	262	327	0.62
Davidson Road.	84	0.5	4.5	400	532	607	0.57
Elibank Road	66	0.6	12.5	1000	434	453	0.52
Fareed Place	15	0.1	5.0	-	91	126	0.69
Frankfort Place	32	0.4	6.6	400	195	246	0.63
Greenland Avenue	36	0.5	10.8	-	155	220	0.71
Havelock Place	10	0.2	6.0	-	67	80	0.60
Isipathana Mawatha	35	0.7	18.0	-	223	285	0.64
Kensington Gardens	21	0.3	8.5	300	120	151	0.63
Kinross Avenue	47	0.4	12.0	700	294	366	0.62
Layards Circle	30	0.4	14.0	350	155	201	0.65
Layards Road	37	0.6	13.0	1000	237	299	0.63
Lorenze Road	52	0.5	9.5	600	251	320	0.64
Mackloid Road	34	0.5	19.5	600	244	312	0.64
Mary's Road	40	0.4	4.0	-	155	201	0.65
Manthri Place & Road	23	0.3	6.3	250	130	161	0.62
Maurice Place	4	0.3	6.3	-	19	22	0.58
Park Lane	17	0.2	19.5	600	113	142	0.63
Park Road	24	0.5	12.8	500	100	141	0.71
Park Terrace	9	0.2	9.8	-	60	74	0.62
Park Way & 30th Lane	23	0.3	8.6	-	175	250	0.71
Ridgeway Place	34	0.4	4.8	300	258	304	0.59
Sagara Road	38	0.4	6.7	775	245	300	0.61
Siripa Lane	17	0.2	7.0	-	71	105	0.74
Siripa Road	50	0.5	11.4	800	173	230	0.66
Skelton Road	53	0.6	12.5	1100	235	339	0.72
Slelton Gardens	18	0.4	12.0	400	69	89	0.64
Spathodia Avenue	23	0.4	6.0	-	71	102	0.72
St. Peter's Place	32	0.4	6.2	450	275	346	0.63
Garden 146	20	0.1	5.0	-	88	92	0.52
Garden 185	8	0.1	9.3	-	45	60	0.67
Total	1176	13.8			6736	8300	0.62

Note : Residential waste collection only.
Except tree cuttings and debris

Table 2 Number of premises in Havelock Town as assessed on 1997

Street	Residential	Commercial	Exempted	Total
Amarasekara Road	86	6	0	92
Ambaghawatte	12	0	1	13
Anderson Road	39	6	0	45
Galle Road	423	98	10	531
Bois Place	8	0	0	8
Castle Lane	63	1	0	64
Udyanapura	104	0	0	104
Clifford Place	35	1	1	37
Davidson Road.	88	9	0	97
Elibank Road	117	7	1	125
Fareed Place	16	2	0	18
Frankfort Place	34	1	0	35
Greenland Avenue	36	0	0	36
Havelock Place	12	2	0	14
Havelock Road	127	68	3	198
Isipathana Mawatha	42	6	7	55
Kensington Gardens	30	3	0	33
Kinross Avenue	54	3	0	57
Layards Circle	30	0	0	30
Layards Road	98	7	0	105
Lorenze Road	62	8	0	70
Mackloid Road	34	1	0	35
Mary's Road	46	1	0	47
Manthri Place & Road	25	0	0	25
Maurice Place	10	0	0	10
Park Lane	17	1	0	18
Park Road	39	4	6	49
Park Terrace	10	0	0	10
Park Way & 30th Lane	23	0	0	23
Ridgeway Place	42	1	1	44
Sagara Road	38	3	0	41
Siripa Lane	18	1	0	19
Siripa Road	61	4	0	65
Skelton Road	83	7	0	90
Slelton Gardens	23	2	0	25
Spathodia Avenue	23	0	0	23
St. Peter's Place	41	0	0	41
Garden 146	20	0	0	20
Garden 185	8	1	0	9
Total	2077	254	30	2361

4. Time Duration for Collection

Total time for collection cycle = Travelling time from transport yard to a particular ward + time for engaging the gang + Total Time for collection +Travelling time to disposal site + waiting time at the queue + return time

Travelling time from transport yard to ward and time for engaging the gang could be minimized by proper coordination. Travelling time to disposal site and return time depends on location of disposal site. During the study period itself the disposal sites changed 3 times and therefore, this factor can be considered only if the life span of a disposal site is at least 1 year.

Having proper access with in and out separate gates, efficient use of bulldozers, and route planning could minimize waiting time at the queue.

It has been found that the average time for loading the compactor trucks, 8 cu.m. and 12 cu.m., varies from 4 hours to 5.3 hours respectively depending on the number of labourers used. i.e. for 8 cu.m. compactor truck 3.7 hours with 5 labourers, 4 hours with 4 labourers and 5.5 hours with 3 labourers. It has been found that the total road length within the Havelock Town Ward is approximately 15 kms. This means the travelling time assuming a travelling speed of 20 km/hr will not exceed 45 minutes. However, as the total loading time is not less than 3 hours & 45 minutes it could be seen that the predominant time consuming factor is the loading time.

According to the sample study 6736 persons are residing in 1176 house holds, which means that the number of persons per house is 6736/1176 = 5.8 which is approximately 6.

Assuming that the compactor truck collects from 4 premises at one collection point, the total collected weight is 6 x 4 x 0.54 x 2 = 26 kg

(The per capita weight - 0.54
Frequency of Collection - 3 times/week)

By assuming that the average weight of the garbage collected through the handcarts, bins etc., is 1000kg per trip for Compactor Truck of Capacity 3.5 tons,

The number of collection points per trip is calculated as 2500 / 26 = 96

Considering the time taken from first collection point to last collection point in a particular collection area, average loading time for a particular vehicle is calculated as follows.

Since the average time taken for collection is 3 hours 30 minutes for a 3.5 Ton. Compactor truck and the number of collection stations are 96, the average time taken to collect residential garbage at one stop is, 3.5 x 60 / 96 = 2.18 minutes.

5. Route planning

The collection time can be minimized by preparing a proper route plan and subsequently educating the workers and the public about the scheduled date and time of collection and obtaining their fullest cooperation as indicated by Tchobanoglous, G. (1977). In order to find out approximate timing initially a route plan has been prepared and run. This was done on a trial and error manner to obtain the best route as well as optimum collection points for all 6 wards in the Colombo West District.

A sample route and the average approximate time taken at each segment of that route are given in the following tables.

Table - 3 Average time taken and schedule time for garbage collection at each segment - Route A Collection dates - Monday, Wednesday and Friday

Compactor truck Capacity - 5500 kg (12 Cu.m.)

Road	No of premises	Time taken (minutes)	Schedule time
Amarasekara Mawatha	92	35	7.00-7.35
Layard's Road	0	3	7.35-7.38
Macleod Road	1	2	7.38-7.40
Sagara Road	41	16	7.40--7.56
Clifford Road	37	19	7.56-8.15
Galle road upto Franckfort pl.	30	15	8.15-8.30
Franckfort Place & return	35	30	8.30-9.00
Galle road /Dickmonds Road	10	10	9.00-9.10
Layard's Road	75	30	9.10-9.40
Lorensz Road	70	27	9.40-10.07
Tea time		18	10.07-10.25
Galle Road upto Kinross Av.	30	35	10.25-11.00
Kinross Av.& return	57	22	11.00-11.22
Galle Road	10	10	11.22-11.32
Castle Lane & return	64	30	11.32-12.00
Total	552	302	

Table - 4 Average time taken and schedule time for garbage collection at each segment - Route B Collection dates - Monday, Wednesday and Friday

Compactor truck Capacity - 3500 kg (8 Cu.m.)

Road	No of premises	Time taken (minutes)	Schedule time
Park Road	49	19	7.00-7.19
Park way & 30th lane	23	15	7.19-7.34
Park Terrace	10	8	7.34-7.42
Udyanapura	104	40	7.42-8.22
185 Garden	9	8	8.22-8.30
146 Garden	20	10	8.30-8.40
Havelock Road	12	14	8.40-8.54
Isipathana Mawatha	42	16	8.54-9.10
Tea time		20	9.10-9.30
Maurice Place	10	10	9.30-9.40
Gas Company H.S.	10	10	9.40-9.50
Greenlands Avenue 1	17	10	9.50-10.00
Greenlands Avenue 2	19	10	10.00-10.10
Manthri Road	15	10	10.10-10.20
Manthri Place	10	8	10.20-10.28
Bois Place	8	8	10.28-10.36
Park Lane	5	5	10.36-10.41
Total	363	221	

Table - 5 Average time taken and schedule time for garbage collection at each segment - Route C
Collection dates - Tuesday, Thursday and Saturday

Compactor truck Capacity - 3500 kg (8 Cu.m.)

Road	No of premises	Time taken (minutes)	Schedule time
Amarasekara Mawatha	0	2	7.00-7.02
Layard's Circle	30	12	7.02-7.14
Layard's Road	3	2	7.14-7.16
Macleod Road	35	14	7.16-7.30
Galle road upto Davidson rd.	12	12	7.30-7.42
Davidson Road	97	36	7.42-8.18
Lorensz Road	3	4	8.18-8.22
Tea time		18	8.22-8.40
Galle Road upto Fareed Pl.	5	10	8.40-8.50
Fareed Place & return	18	10	8.50-9.00
Galle Road	5	13	9.00-9.13
St. peter's place	41	15	9.13-9.28
Ridgeway Place	44	17	9.28-9.45
Galle Road	7	10	9.45-9.55
Mary's Road	47	18	9.55-10.13
Galle Road	15	15	10.13-10.28
Total	362	208	

Table - 6 Average time taken and schedule time for garbage collection at each segment - Route D
Collection dates - Tuesday, Thursday and Saturday

Compactor truck Capacity - 5500 kg (12 Cu.m.)

Road	No of premises	Time taken (minutes)	Schedule time
Amarasekara Mawatha	3	5	7.00-7.05
Elibank Road	125	48	7.05-7.53
Dickmonds Road	0	7	7.53-8.00
Anderson Road	45	17	8.00-8.17
Skelton Road	90	35	8.17-8.52
Skelton Gardens	25	10	8.52-9.02
Havelock Road	25	14	9.02-9.16
Havelock Place	12	6	9.16-9.22
Havelock Road upto Vajira Rd.	40	25	9.22-9.47
Ambagahawatte	13	10	9.47-9.57
Tea time		18	9.57-10.20
Havelock Rd. upto Spatodia Av.	20	20	10.20-10.40
Spatodia Avenue	48	20	10.40-11.00
Siripa Lane	19	15	11.00-11.15
Siripa Road	65	25	11.15-11.40
Total	530	275	

It must be noted that there are two 5 cu.m. skip bins located at Havelock road - park Road Junction (Havelock Town Depot) and at Bambalapitiya flats, that are removed daily. Further for roads with heavy traffic congestion and narrow roads, household garbage could be collected by handcart and then transferred to the compactor truck at a suitable point.

Using the above the public could be notified more precisely of the exact date and timing of garbage collection. Therefore it could be expected that there would be better public corporation and through which improved efficiency. However it must be noted that as the conditions are subject to continuous change regular monitoring, training of crewmembers, drivers and other staff, and other improvements are necessary. It was also noted from an interview survey that the consumers were willing to separate different types of garbage such as paper, tins, plastic etc., at the source level on condition that they would be collected at least once a week.

6. Collection from the large bins of capacity 5m^3 or tractor trailers

Markets, Flats, Hospitals, Schools, Large Buildings, Departmental stores and Production oriented Industries are places, which can be recommended for large bins. Separate individual garbage collection cubicles with locking facilities, as a big temporary storage can be provided for places like apartments or flats. Separate transportation and collection system is required for such places which would have large bins (either 5 Cum. skip bins or tractor-trailers).

Collection Route for this type has to be planned according to

1. Filling time of container
2. Traffic congestion

It is recommended to start with an empty bin/ trailer with skip hoist/ tractor. The empty container should be replaced for the solid waste full container at the first collection point. After unloading the container at the dumping site, moving to the next collection point can be done directly without going to first collection point. This will reduce the travelling time per trip and the cost.

To carryout the above process it is recommended to have at least three trailers per tractor (in order to park the trailer at collection points) or /and five skip bins per skip hoist depending on the distance/travelling time from the large bin collection point to the disposal site. And also it is recommended to allow these particular vehicles to unload garbage at the disposal site without waiting in the queue, as these don't possess any loading time unlike the compactor trucks.

Average cost of trailer is 10% of the tractor Engine and average cost of skip bin is less than 10% of the skip hoist. i.e. Cost of four-wheel tractor is Rs. 900,000.00 while Cost of a trailer is Rs.95,000.00. as at 1996. Therefore possessing 3 or more trailers to a tractor could be said to be economically viable specially considering time taken to go to the dumping site.

In order to do one trip (go, dump the solid waste at disposal site 10km away and return) on the average a tractor takes 75 minutes. Considering unmounting an empty trailer and then mounting of a trailer full of waste the time on the average is 90 minutes. If 3 trailers are considered this will amount in total to 90 x 3 = 270 minutes. Considering an effective day of 6 hours for trailers per tractor is the ideal condition. However if this is not possible at least 3 is recommended.

7. Variability of residential per capita waste generation

The residential per capita waste generations varies according to the income group. Therefore here an analysis has been performed to calculate the per capita waste generation of low and high-income groups of the Havelock Town ward.

The low-income per capita waste generation was found to be 0.49 kg / per day from Udyanapura and Ambagahawatte data in Table - 1. The high-income per capita waste generation from the same Table was calculated to be,

(9269 - 501 - 32) / [2 x (7416 - 516 - 33)] = 0. 64 kg/day

Table - 7 Household Income and Expenditure by household 1995/96

Income Deciles	Income Group (Rs.)	Mean Income (Rs.)	Share of income to total household Income	Median Income (Rs.)	Mean Expenditure per month(Rs.)
Total		6579	100	4165	6247
1	<1604	1139	2	1210	2795
2	1604-2294	1938	3	1950	3153
3	2295-2943	2614	4	2600	3635
4	2944-3517	3210	5	3200	4231
5	3518-4165	3830	6	3820	4449
6	4166-4982	4515	7	4504	5262
7	4983-6197	5535	8	5500	6324
8	6198-8145	7092	11	7043	7196
9	8146-11960	9750	15	9700	9571
10	>11960	26187	40	17200	16534

Source: Household Income and expenditure survey –1995/96
Department of Census and Statistics

From the above table it could be seen that the households with a monthly income of less than Rs.6197 to be in the Low Income Group, which consist of 70% of the population.

Residential per capita waste generation - (x kg/day)

Income Group	Income (Rs/month)	Population (%)
Low	< 6197	70%
High / Medium	> 6198	30%

$X = [(X_{H/M} * 30\% \text{ of pop}) + (X_L * 70\% \text{ of pop})] / \text{pop}$

$X_{H/M}$ - per capita waste generation of high and middle-income group 0.64 kg/day

X_L - per capita waste generation of low-income group 0.49 kg/day

Average residential per capita waste generation,

$= [(X_{H/M} * 30\% \text{ of pop}) + (X_L * 70\% \text{ of pop})] / P$

$= [0.64 \times 30\% P + 0.49 \times 70\% P] / P$

$X = 0.54$ kg/day

8. Relationship between coverage area and vehicle capacity

The number of collection points per vehicle per shift, for any semi residential area can be calculated from the model given below.

x = No of residential collection points

y = No of Non-residential Collection points

a = Average collection per residence (kg)

b = Average collection at each non-residential premise(kg). Premises that generate more than 50kg/day is taken as to be collected daily

c = Capacity of the vehicle(kg)

$$a*x + b*y = c$$

x/y = ratio of residential & Non residential premises

The variables a and b depend upon,

1. frequency of collection
2. average number of persons per household
3. Average collection per non-residential organization.

Sample calculations for two wards of Colombo City are shown below. Number of residential and non-residential premises for each ward for our calculation, was taken from the Assessors Department of CMC. Average Collection for non-residential organizations was found us-

ing the results of the sample study. The figure used for per capita garbage generation will be applicable only to Colombo City and for areas of similar characteristics. Therefore for any other area, if an accurate figure for C is desired a sample study has to be carried out to determine a and b.

Given below are the calculations for a house hold size of 6. The frequency of collection of residential garbage has been varied. The non-residential garbage has been considered to be collected daily but the quantity has been considered to vary. Similar calculations could be performed varying the above parameters including per capita residential waste generation.

Generation of Garbage per house average household size 6

per capita residential garbage generation

= 0.54k g/day

No of persons per house = 6

Frequency of collection every other day

= 0.54 * 6 * 2 = 6.5 kg

Frequency collection every 3 days

= 0.54 * 6 * 3 = 9.7kg

Collection for 3 times /week

= 0.54 * 6 * 7/3 = 7.6 kg

Collection for 2 times / week

= 0.54 * 6 * 7/2 = 11.34kg

Using the above equation a model has been developed as an Excel spreadsheet and the following results were obtained using the model.

Here "a" has been calculated as above and substituted in the model. "b" is assumed to vary as in the table below. "c" is a fixed value since it refers to the vehicle design capacity. The total resident/non-resident premises for a ward or district have been obtained from Assessor's Department of the CMC. Using these values and the above equation the exact number of residential to non-residential premises that must be covered in order to bring the garbage removal vehicle to optimum capacity could be calculated.

Determining the number of collection points per vehicle

Table - 8 Application of equation ward wise

6 persons per house
Collection from non residential premises generating more than 50kg/day is taken as daily

Ward	a	B	C	residential	Non Residential	x	y
HAVLOCK	7.5	10	5500	2100	300	616	88
TOWN	7.5	11	5500	2100	300	606	87
	8.0	10	5500	2100	300	583	83
	8.0	11	5500	2100	300	575	82
	8.5	11	5500	2100	300	546	78
	9	10	5500	2100	300	527	75
	9	11	5500	2100	300	520	74
	9	12	5500	2100	300	513	73
	9.7	10	5500	2100	300	494	71
	9.7	11	5500	2100	300	488	70
	9.7	12	5500	2100	300	482	69
Wellawatte	9.7	11	5500	2100	800	396	151
North	8.0	10	5500	2100	800	466	177
	7.5	10	5500	2100	800	486	185
Wellawatte	9.7	11	5500	1500	450	423	127
South	8.0	10	5500	1500	450	500	150
	7.5	10	5500	1500	450	524	157

The same principal is applied for different types of vehicles and the result are shown below.

Table - 9 Application of equation equipment capacity wise

	a	B	C	Residential	Non-Residential	x	y
by 8 Cu.m. vehicles							
	9.7	10	3500	2100	300	315	45
	9.7	11	3500	2100	300	311	44
	9.7	12	3500	2100	300	307	44
	8.5	11	3500	2100	300	348	50
	9.0	11	3500	2100	300	331	47
	9.0	10	3500	2100	300	336	48
	9.0	11	3500	2100	300	331	47
	8.5	10	3500	2100	300	353	50
	7.5	11	3500	2200	300	389	53
	6.5	11	3500	2200	300	438	60
	8.0	10	3500	2200	300	374	51
	7.5	10	3500	2200	300	395	54
	6.5	10	3500	2200	300	445	61
by 5 Cu.m. Skip Bin							
	9.5	11	1250	2200	300	114	15
	8.0	11	1250	2200	300	132	18
	7.5	11	1250	2200	300	139	19
	6.5	11	1250	2200	300	156	21
	8.0	10	1250	2200	300	133	18
	7.5	10	1250	2200	300	141	19
by 3.5 Cu.m. Tractors							
	9.5	11	1000	2200	300	91	12
	8.0	10	1000	2200	300	107	15
	7.5	10	1000	2200	300	113	15

9. Norms for other solid waste collection activities

The norms for road sweeping have been obtained by a work study. Here observations were obtained for a one month period at varying locations. The time taken for laborers to sweep a measured distance has been calculated and the average figures for road sweeping are given below. However it must be noted that these values are valid for conditions such as fairly good road surfaces and moderate traffic congestion. In addition the same person collects the waste and puts it into a handcart.

The norm for road sweeping 1 laborer / hour = 750 square meters. (Considering a one month period at varying locations and the time taken to sweep a known distance)

Road brushing has to be performed by a group as unlike sweeping the waste is heavier and the task is more difficult. It is observed that a group of 5 persons is the optimum. The equipment required would be 1 handcart, 4 brushes and 1 shovel.

Similarly the norms for road brushing has been found to be 350 square meters per hour per group under moderate traffic conditions. (Considering a one month period at varying locations and the time taken to brush a known area)

The norm for poster removal by machine has been found to be 60 square meters per hour including removal of waste if the posters are in one location only.

10. Summary and Conclusion

A study has been performed in order to allocate resources for collection and transportation of solid waste. Initially a route planning procedure has been presented.

Route planning basically has been considered as a function of route balancing and micro routing. All elements related to these factors have also been analyzed.

The total time in the collection cycle per trip has been investigated taking into consideration the Havelock town area and it has been found that the average time taken at one collection point is 2.18 Minutes in the case 4 laborers in one crew.

Markets, Flats, Hospitals, Schools, Large Buildings, Departmental stores and Production oriented Industries are places, which large bins have been recommended with daily removal. Separate individual garbage collection cubicles with locking facilities, as big temporary storage should be provided for places like apartments or flats. Separate transportation and collection system is required for such places which would have large bins (either 5 Cum. skip bins or tractor-trailers).

It is also recommended to have at least three trailers per tractor (in order to park the trailer at collection points) or / and five skip bins per skip hoist depending on the distance/travelling time from the large bin collection point to the disposal site.

According to a study done on 1176 households, which possessed 6736 persons the number of residents per house has been calculated as 5.8. It has been found that the residential per capita waste generations varies according to the income group. The low-income per capita waste generation was found to be 0.49 kg / per day and the high income per capita waste generation was calculated to be 0. 64 kg/day. The average per capita residential collection has been found to be 0.54 kg.

A model has been developed to calculate the feasible number of collection points per vehicle per shift, for any semi residential area in order to optimize capacity of waste transportation vehicle. This model could be used for route planning in any location with similar characteristics.

The norms for road sweeping have been found to be 750 square meters per laborer per hour. Similarly the norms for road brushing has been found to be 350 square meters per hour per group of 5 persons. The norm for poster removal by machine has been found to be 60 square meters per hour including removal of waste if the posters are in one location only.

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