2.2 Forecast of the Future Solid Waste Generation Volume

In order to obtain basic data for formulation of solid waste management system of the year 2000, the future solid waste generation volumes of the entire city area and each zone (zoned by dividing the entire city area) were forecast.

The planned collection volume was determined based on these forecast generation volumes.

As for market waste which is thought most suitable to composting, the generation volume for the year 2000 was separately forecast and the results utilized in determination of compost plant locations.

2.2.1 Forecast of the future solid waste generation volume in the city

(1) Forecasting equation

Solid waste is generated as the result of material consumption. Material consumption is carried on in daily life and socio-economic activities. Comprehensively speaking, these socio-economic activities are able to be represented by economic indices like Gross Provincial Products. Accordingly, it is also possible to estimate solid waste volume by relation with the economic indices. The relation between GPP (Gross Provincial Products) of Bangkok city in the past and solid waste generation volume was formulated as follows:

$$G = 5.64(P-78.1) + 826 \qquad \text{(Eq. 2-1)}$$

where, G: solid waste generation volume per year (1,000 t)
P: GPP, in billion Baht

(For the establishment of the above-mentioned equation, refer to Appendix 2.10).

By using the above-mentioned equation, future solid waste generation volume was estimated as per the work flow shown in Fig. 2.1.

(2) Forecast of the future GPP

According to the work flow shown in Fig. 2.2, the future GPP of Bangkok city was estimated.

i) Forecast of the future GDP

a. Until the year 1981

The Fourth National Economic and Social Development Plan (1977 - 1981, by NESDB) (referred to as 4th NESDP) sets the target of annual GDP growth rate at 7%. In the results from 1976 to 1979, GDP seemed likely to reach the target.

Therefore, outputs for each industry in 1980 and 1981 were calculated by applying the planned growth rates of each industry to an output of the corresponding industry in the year 1979. GDP of the year 1980 and 1981 were obtained as a sum of the outputs of all industries.

Fig. 2.1 Work flow of the estimation of the future solid waste generation volume

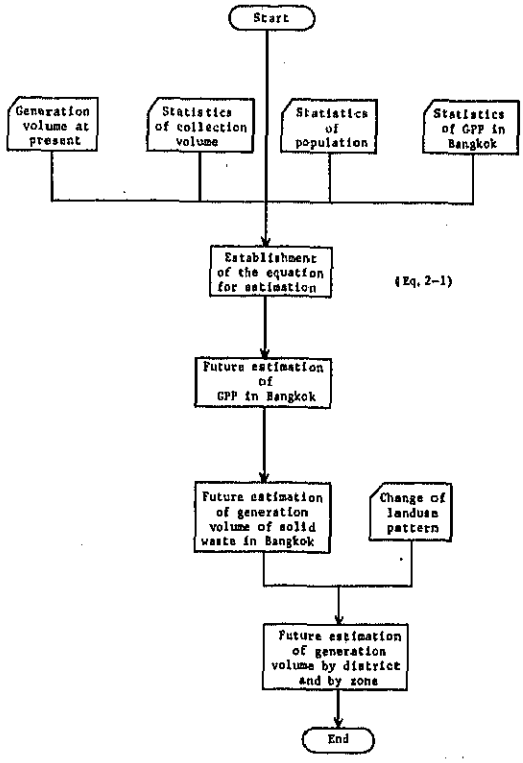
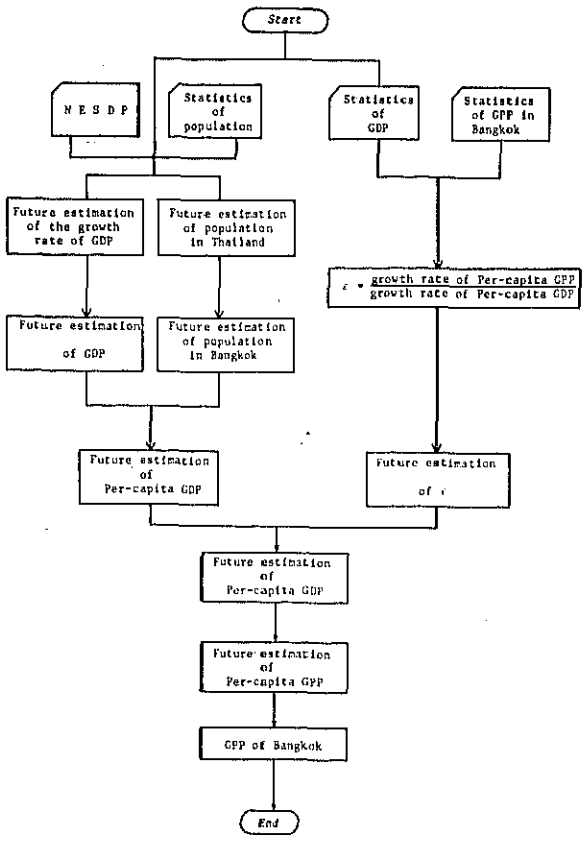


Fig. 2.2 Work flow of the estimation of gross provincial products



b. Forecast from 1982 to 2000

Since the target of GDP growth rate during this period is not fixed yet, GDP growth rates of each period were assumed by referring to the recent reports on traffic surveys to be 6% per year during the period from 1982 to 1991, and 5% per year from 1992 to 2000.

The GDP forecasts by this method are shown in Table 2.9.

ii) Forecast of population for Thailand

According to the 4th NESDP, the growth rate of population for Thailand is targeted to decline from 2.5% of the year 1977 to 2.1% by 1981. Change of the population in the recent years implies that it will be easy to reach the target by 1981.

With reference to the population growth rate of 2.1 percent, future population growth rates and future population estimated in the 4th NESDP, population for Thailand was forecast by the Study team as shown in Table 2.9.

iii) Forecast of the future population in Bangkok city

The future population in Bangkok city is forecast by estimating future population growth rate in Bangkok city with reference to that of Thailand (for details of estimating method, refer to Appendix 2.12).

The forecast value of the future population in Bangkok city is shown in Table 2.8. The future population of each district in Bangkok city is forecast, applying the following two methods (for details of estimating methods, refer to Appendix 2.12):

a. For the central districts, the past annual growth trend was extended into the future.

b. For the surrounding districts where the land-use pattern is changing remarkably, future district population is based on change in land-use.

The forecast value of the future population in each district is shown in Table 2.10.

iv) Forecast of future GPP

The per-capita GPP growth rate is forecast with reference to the per-capita GDP growth rate. GPP of Bangkok city is forecast as the product of the future population in Bangkok city and the per-capita GPP (for the details of the estimation procedure, refer to Appendix 2.13).

(3) Future solid waste generation volume in Bangkok city

Table 2.11 shows the forecast future solid waste generation volume in Bangkok city up to the year 2000. The forecast generation unit in the year 2000 is 740 grams per capita per day.

Table 2.9 GDP, GPP, and population

	GDP of Thailand at 1972 prices (billion Baht)	GPP of Bangkok Metropolis at 1972 prices (billion Baht)	Population of Thailand (1,000 persons)	Population of Bangkok Metropolis (1,000 persons)
1969	136.307			
1970	146.216		35,550	3,568
1971	156.308		36,820	3,707
1972	162.865		38,359	3,829
1973	179.936	44.4	39,950	3,967
1974	188.971	47.5	41,334	4,130
1975	203.514	50.997	42,391	4,349
1976	222.509 (221.225)	56.788	43,214	4,546
1977	238.841 (237.173)	63.197	44,273	4,743
1978	266.840 (261.097)	70.350	45,222	4,871
1979	284.747 (276.907)	78.103	46,114	5,000
1980	304.2 (294.376)	85.6	47,200 (46,961)	5,180 (5,153)
1985	410.2	126.4	52,200	5,900
1990	548.9	178.3	57,300	6,630
1995	707.3	233.9	62,500	7,360
2000	902.7	300.9	67,600	8,030

Note: The figures in the year 1980 onwards were estimated by the Study team.

Actual figures of population in 1980 are shown in parentheses.

The source of GDP is "Gross Regional and Provincial Product, 2522, NESDB".

GDP figures in parentheses in 1976 - 1980 are from the "National Income of Thailand, 1980 Edition, NESDB".

Table 2.10 Forecast of future population by district

District Name	Population (1,000 persons)		Ratio
	1979	2000	2000/1979
Phra Nakhon	125	101	0.808
Pom Prap	194	173	0.892
Pathum Wan	233	284	1.22
Sam Phan Thawong	78	71	0.91
Bang Rak	126	150	1.19
Yannawa	375	731	1.95
Dusit	462	565	1.22
Phayathai	514	704	1.37
Huai Khwang	195	290	1.49
Phra Khanong	502	1,048	2.09
Bang Khen	367	672	1.83
Bang Kapi	219	490	2.24
Nong Chok	50	69	1.38
Minburi	53	78	1.47
Lat Krabang	41	67	1.63
Thonburi	257	342	1.33
Khlong San	141	141	1.00
Bangkok Noi	379	510	1.35
Bangkok Yai	100	136	1.36
Bang Khun Tian	197	480	2.44
Phasi Charoen	176	319	1.81
Rat Burana	108	376	3.48
Taling Chan	65	153	2.35
Nong Khaem	40	80	2.0
Total	5,000	8,030	1.606

Forecast by the Study team.

Table 2.11 Forecast of the future solid waste generation volume

Year	Population in Bangkok (1,000 persons)	Gross Provincial Products		Generation Volume (t/d)
		Amount at 1972 prices (Billion Baht)	Share in GDP (%)	
1980	5,180	85.6	28.1	2,380
1985	5,900	126.4	30.8	3,010
1990	6,630	178.3	32.5	3,810
1995	7,360	233.9	33.1	4,670
2000	8,030	300.9	33.3	5,710

Forecast by the Study team.

Note: Generation volume in a day is calculated by dividing the generated volume in a year by 365 days.

2.2.2 Solid waste generation volume by district and by zone

To provide reference data for the study of collection and transportation system, solid waste collection volume in Bangkok city obtained in section 2.2.1 was divided by districts and by zones.

Change of the generation volume was forecast based upon a comparison of the present and the future (the year 2000) land-use patterns of the districts and the zones.

Land-use maps of the present and the year 2000 were obtained from Department of Town and City Planning (DTCP) of Ministry of Interior and are shown on Figs. AP 2.4 and 2.5 in Appendix 2.14.

Details of the estimation method are shown in Appendix 2.14. Table 2.12 shows the names of districts and subdistricts by zone.

Forecast generation volume by district and by zone are shown in Table 2.13.

Generation unit by area was taken as generation intensity. The center of the solid waste generation in an entire city is determined by averaging the coordinates of zones with weight of generation volume. Fig. 2.3 shows the generation intensity and the center of generation of solid waste in Bangkok city. Generation unit by district is shown in Appendix 2.15.

2.2.3 Collection and disposal plan

(1) Annual plan

The annual collection plan of solid waste is developed to improve the collection from the present level of about 80 percent collection, achieving almost 100 percent collection in the year 2000. Table 2.14 shows the annual collection plan (The collection rate in percent in the year 2000 is planned to be 97 percent because of an estimated disposal rate at source of 3 percent).

Table 2.12 Zone table

Zone No.	District and Sub-district Name
1	Phra Nakhon
2	Pom Prap
3	Pathum Wan
4	Sam Phan Thawong
5	Bang Rak
6	Yannawa Yannawa Wat Phra Khrai Bang Kolaem Thung Wat Don Bang Khlo
7	Yannawa Thung Mahamek Bang Pong Pang Chongnonsi
8	Dusit Dusit Wachira Phayaban Suan Chitrada Siyaek Mahanak Thanon Nakhon Chaisri
9	Dusit Bang Su
10	Phayathai Thanon Petchaburi Thung Phayathai Makkasan Thanon Phayathai
11	Phayathai Samsen Noi
12	Huai Khwang Bang Kapi
13	Huai Khwang Huai Khwang Ding Daeng Samsen Nok
14	Phra Khanong Phra Khanong Khlong Tan Khlong Toey
15	Phra Khanong Suan Luang
16	Phra Khanong Bang Na Bang Chak
17	Phra Khanong Nong Bon Dok Mai
18	Phra Kharong, Prawet
19	Bang Khen, Lat Yao
20	Bang Khen, Song Hong
21	Bang Khen, Si Kan
22	Bang Khen Talat Bang Khen
23	Bang Khen Anusawari Thareng Khlong Thanon Sai Mai O Ngoen
24	Bang Kapi Lat Phrao Charakhe Bua
25	Bang Kapi Khlong Chan Wang Thong Lang
26	Bang Kapi Khong Kum Kanna Yao
27	Bang Kapi, Hua Mak
28	Bang Kapi Saphan Sung
29	Nong Chok
30	Minburi
31	Lat Krabang
32	Thonburi
33	Khlong San
34	Bangkok Noi Bang Yi Khan Bang Phlat Bang Bamru Bang O
35	Bangkok Noi Sirirat Bang Chang Lo Bang Khunnon Bang Khun Sri
36	Bangkok Yai
37	Bang Khun Tian Chom Thong Bang Khun Tian Bang Mot Bang Klo
38	Bang Khun Tian Bang Bon Ta Kham Samae Dam
39	Phasi Charoen Bang Wa Bang Duan Bang Chak Bang Waek Khlong Khwang Pak Khlong Khu Ha Sawan
40	Phasi Charoen Bang Khae Bang Khae Nua Bang Phai
41	Rat Burana Rat Burana Bang Pakok
42	Rat Burana Bang Mot Tung Kru
43	Taling Chan
44	Nong Khaem

Table 2.13 Solid waste generation volume by district and by zone

(Unit: t/d)

District Name	Zone Number	Generation Volume	
		District	Zone
Phra Nakhon	1	280	
Pom Prap	2	145	
Pathum Wan	3	236	
Sam Phan Thawong	4	150	
Bang Rak	5	203	
Yannawa	6	502	248
	7		254
Dusit	8	321	190
	9		131
Phayathai	10	406	153
	11		253
Huai Khwang	12	242	58
	13		184
Phra Khanong	14	901	233
	15		119
	16		189
	17		225
	18		135
Bang Khen	19	360	146
	20		38
	21		35
	22		44
	23		97
Bang Kapi	24	372	79
	25		81
	26		138
	27		37
	28		37
Nong Chok	29	13	
Minburi	30	48	
Lat Krabang	31	29	
Thonburi	32	291	
Khlong San	33	139	
Bangkok Noi	34	432	237
	35		195
Bangkok Yai	36	106	
Bang Khun Tian	37	152	96
	38		56
Phasi Charoen	39	132	67
	40		65
Rat Burana	41	175	76
	42		99
Taling Chan	43	37	
Nong Khaem	44	38	
Total		5,710	

Estimated by the study team.

Note: Generation volume per day is obtained by dividing the generated volume per year by 365 days.

Fig. 2.3 Distribution map of solid waste generation intensity

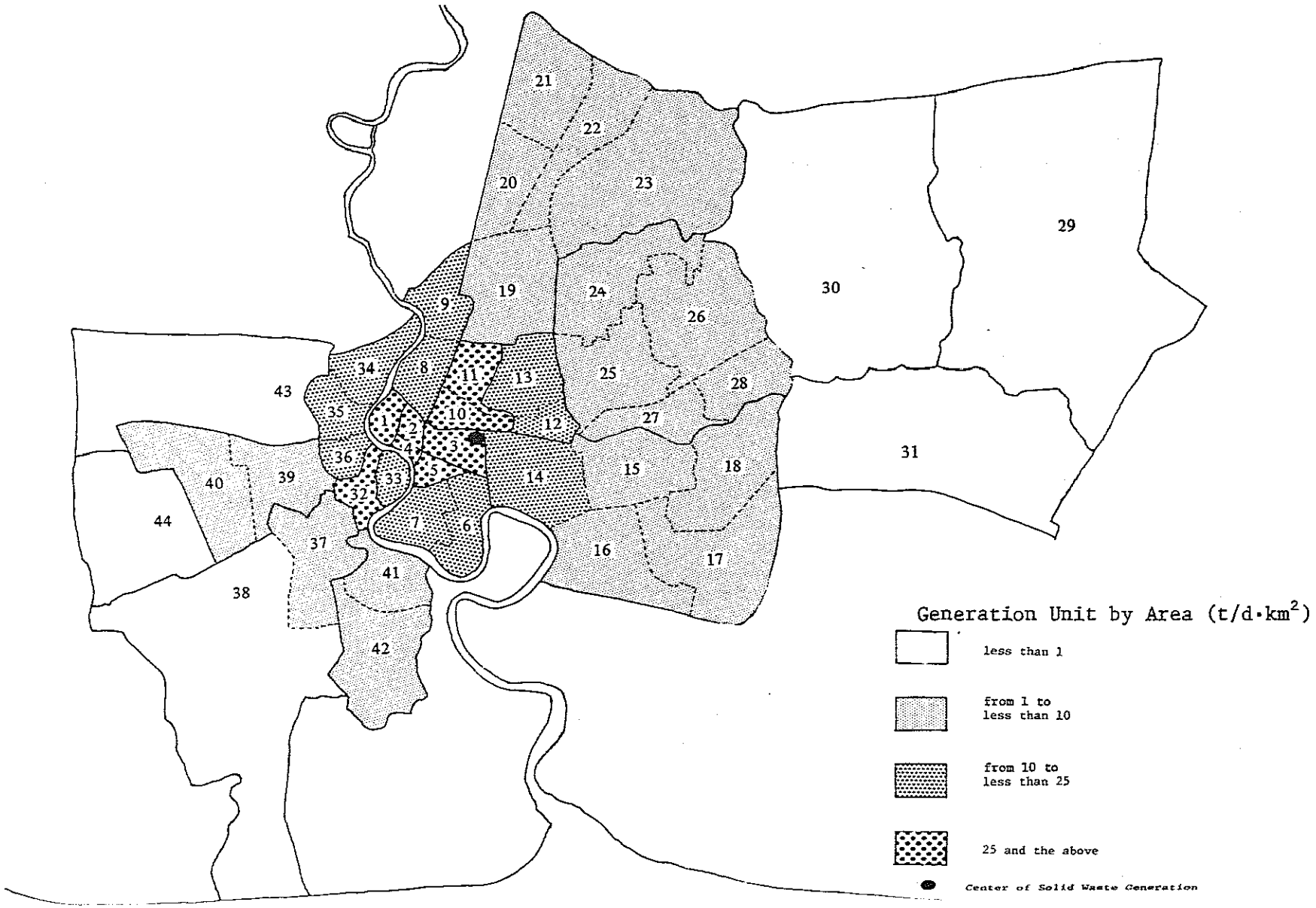


Table 2.14 Solid waste collection and disposal plan

Year	Generation Volume (t/d)	Percentage of Solid Waste Collection (%)	Collection Volume (t/d)	Percentage of Material Retrieval (%)	Disposal Volume (t/d)
1981	2,490	80.6	2,008*	5	1,912*
1982	2,610	82	2,140	5	2,040
1983	2,740	82	2,250	5	2,140
1984	2,870	82	2,350	5	2,240
1985	3,010	82	2,470	4	2,380
1986	3,160	83	2,620	4	2,520
1987	3,310	84	2,780	4	2,670
1988	3,470	85	2,950	4	2,840
1989	3,630	86	3,120	4	3,000
1990	3,810	87	3,310	3	3,210
1991	3,970	88	3,490	3	3,390
1992	4,130	89	3,680	3	3,570
1993	4,300	90	3,870	3	3,760
1994	4,480	91	4,080	3	3,960
1995	4,670	92	4,300	2	4,220
1996	4,860	93	4,520	2	4,430
1997	5,060	94	4,760	2	4,670
1998	5,270	95	5,010	2	4,910
1999	5,480	96	5,260	2	5,160
2000	5,710	97	5,540	1	5,490
2005	6,710	97	6,510	1	6,440
2010	7,610	97	7,380	1	7,310

Estimated and planned by the Study team.

Note: Volumes of generation, collection and disposal per day are calculated by dividing volumes per year by 365 days.

The difference between collection volume and disposal volume means the volume retrieved on the way from the collection place to the disposal sites.

The volumes in the year 2000 were estimated on the assumption of a growth rate 4% during 2000 and 2005 and 3% during 2006 and 2010.

* Figures in 1981 are the actual values.

(2) Solid waste collection volume by districts by zones (the year 2000)

Solid waste collection volume by districts by zones in the year 2000 is planned as shown in Table 2.15, setting a high collection rate in the central districts and low collection rate in the suburban districts. The planned collection rates per year and per district in 1983 through 2000 are shown in Appendix 2.16.

2.2.4 Forecast of the future market waste volume

Because market waste is suitable for composting, it should be hauled to the compost plant. To serve as basic reference data in planning transportation of solid waste collection, market waste volume was estimated taking into account population growth and the accompanying increase in foodstuff consumption (for estimation process, refer to Appendix 2.17). The market waste volume in the year 2000 is forecast to be approximately 260 tons per day.

Table 2.15 Solid waste collection volume by districts by zones (Year 2000)

(Unit : t/d)

District Name	Zone Number	Collection Volume	
		District	Zone
Phra Nakhon	1	277	277
Pom Prap	2	144	144
Pathum Wan	3	234	234
Sam Phan Thawong	4	149	149
Bang Rak	5	201	201
Yannawa	6	477	236
	7		241
Dusit	8	318	188
	9		130
Phayathai	10	402	151
	11		251
Huai Khwang	12	235	56
	13		179
Phra Khanong	14	874	226
	15		115
	16		183
	17		219
	18		131
Bang Khen	19	349	141
	20		37
	21		34
	22		43
	23		94
Bang Kapi	24	361	77
	25		79
	26		134
	27		35
	28		36
Nong Chok	29	12	12
Minburi	30	46	46
Lat Krabang	31	28	28
Thonburi	32	278	278
Khlong San	33	133	133
Bangkok Noi	34	412	226
	35		186
Bangkok Yai	36	101	101
Bang Khun Tian	37	145	92
	38		53
Phasi Charoen	39	126	64
	40		62
Rat Burana	41	167	73
	42		94
Taling Chan	43	35	35
Nong Khaem	44	36	36
Total		5,540	

Estimated and planned by the Study team.

2.3 Forecast of the Future Solid Waste Properties

In order to provide the necessary information for examination of processing technology such as composting and incineration, future properties of solid waste were forecast.

Reception pits in compost plants receive household waste, market waste and the other miscellaneous waste from various dischargers; therefore, the reception pit waste is considered as representing a typical cross section of solid waste generated in Bangkok city.

From this point of view, the reception pit waste was taken as the basis of the forecast.

Work flow of the forecast of the future solid waste properties is shown in Fig. 2.4.

2.3.1 Forecast of the future solid waste physical composition (dry basis)

(1) Forecast method

The percentage of solid waste component in the total solid waste volume was obtained by using the following equation:

$$r_j(i) = 100A_j(i)r_j(1980) / A_j(i)r_j(1980) \qquad \text{(Eq. 2-2)}$$

where, $r_j(i)$ is a share (%) of the component (j) in a total solid waste volume in the year 'i'.

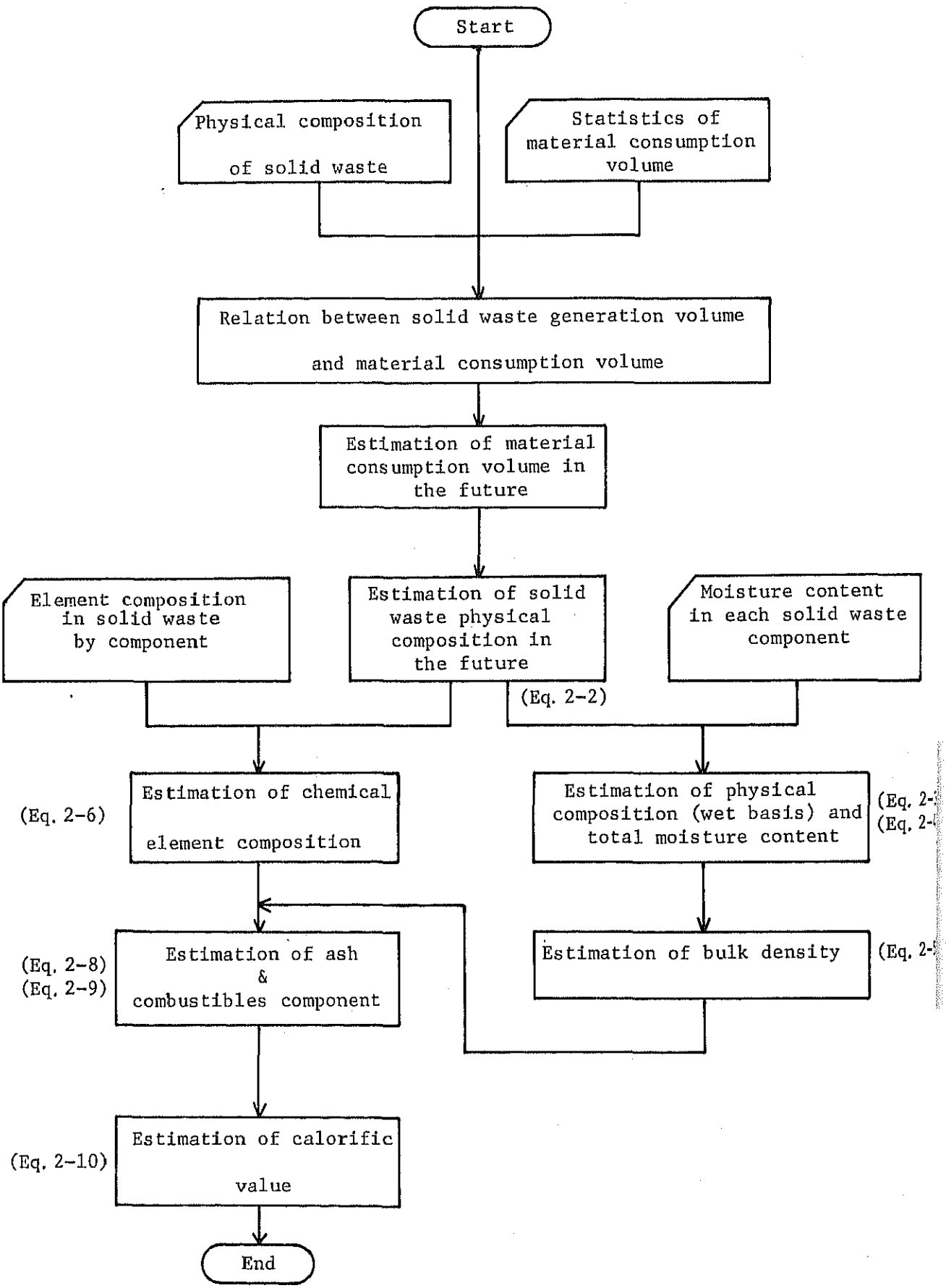
$A_j(i)$ is a growth rate of the component 'j' volume in the 'i' year to that in 1980.

Solid waste component volume is proportionally related to the consumption materials disposal volume, and to the consumption volume of the materials. Thus the growth rate of the consumption volume of related materials was adopted as the basis for forecasting individual solid waste components. (The details of the forecast method is described in Appendix 2.18).

The correspondence between solid waste component and the related material is shown below.

Solid waste component	Related material studied
Garbage	Foodstuff
Paper waste	Paper
Textile waste	Textile
Plastic waste	Plastic
Rubber waste	Rubber
Leather waste	Leather
Ferrous metal waste	Steel and iron
Non-ferrous metal waste	Aluminum, copper
Glass waste	Glass
Ceramic waste	Ceramics, earthenware
Bone, shell	Foodstuff
Wood and plant waste	Foodstuff and others

Fig. 2.4 Forecast of physical composition and chemical properties of solid waste



(2) Forecast of growth rate of future material consumption volume

Growth rate of related consumption material volumes are forecast through time series analysis or correlation analysis with GDP, with reference to various economic statistics obtained from the National Statistical Office, the Bank of Thailand, and so forth.

The value to be forecast by these methods is for the whole of Thailand. The growth rate of the related consumption materials in Bangkok city is obtained by adjusting the value for the whole of Thailand considering the future change of the city's GPP share of GDP. Basic data used in the estimation are shown in Appendix 2.19. The growth rates of related material consumption volumes in Bangkok city are shown in Table 2.16 by indices using the 1980 value as 100.

Table 2.16 Forecast of the future material consumption volume

	Index of consumption volume (the value of the year 1980 = 100)				
	1980	1985	1990	1995	2000
Paper	100	161	242	330	436
Textile	100	161	241	328	433
Foodstuff	100	142	194	249	316
Grass and Wood	100	137	182	229	285
Plastics	100	161	240	327	432
Rubber	100	143	185	224	261
Leather	100	158	218	273	328
Steel	100	144	206	281	378
Aluminum and Copper	100	152	220	293	381
Glass and Glassware	100	152	219	291	378
Ceramics	100	138	184	232	290

Estimated by the Study team

(3) Results of forecast

Future physical compositions on a dry basis obtained by using Eq. 2-2 and the values in Tables 2.6 and 2.16 are shown in Table 2.17.

2.3.2 Forecast of physical composition (wet basis), moisture content and bulk density

(1) Forecasting method

i) Individual moisture content in each solid waste component

Applying the results of the "Survey of the Properties and Generation of Solid Waste", the equations to calculate individual moisture content in each solid waste component were formulated.

The formulas are shown in Appendix 2.20.

Table 2.17 Forecast of physical composition of solid waste

(Unit : percentage on dry weight basis)

			Year				
			1980	1985	1990	1995	2000
1. Combustibles			71.5	72.1	72.5	72.6	72.6
Breakdown	Paper		18.0	19.5	20.8	21.5	22.1
	Textile		4.4	4.8	5.1	5.3	5.4
	Garbage		16.5	15.8	15.2	14.9	14.6
	Grass and Wood		19.6	18.1	17.0	16.2	15.7
	Plastics		10.3	11.2	11.8	12.2	12.5
	Rubber & Leather		2.7	2.7	2.6	2.5	2.3
	Breakdown	Rubber	1.1	1.0	1.0	0.9	0.8
		Leather	1.5	1.6	1.5	1.5	1.4
		Other	0.1	0.1	0.1	0.1	0.1
2. Incombustibles			21.0	20.4	20.0	19.9	19.9
Breakdown	Ferrous metal		4.5	4.4	4.4	4.6	4.8
	Non-ferrous metal		0.3	0.3	0.3	0.3	0.3
	Glass		5.5	5.6	5.7	5.8	5.8
	Ceramics, others		10.3	9.8	9.3	9.0	8.8
	Breakdown	Stones, ceramics	5.0	4.7	4.4	4.2	4.1
		Bones, Shells Crusts	5.3	5.1	4.9	4.8	4.7
	Dry cells		0.4	0.3	0.3	0.2	0.2
3. Miscellaneous			7.5	7.5	7.5	7.5	7.5
4. Total			100.0	100.0	100.0	100.0	100.0

Estimated by the Study team.

ii) Physical composition (wet basis) and moisture content

If physical composition on dry basis and individual moisture content of each solid waste component are known, physical composition on wet basis and moisture content are obtainable from the following equations:

$$g_i' = 100 \frac{\frac{g_i}{1 - W_i/100}}{\sum_i \frac{g_i}{1 - W_i/100}} \qquad \text{(Eq. 2-3)}$$

$$W = \alpha \sum_i g_i' W_i / 100 \qquad \text{(Eq. 2-4)}$$

where, g_i : Physical composition (dry basis) of component 'i' (wt%)

W_i : Moisture content of component 'i' (wt%)

g_i' : Physical composition (wet basis) of component 'i' (wt%)

W : Total moisture content (wt%)

α : Coefficient of adjustment obtained from the equation below.

$$\alpha = Wa_{80}/W_{80}$$

where, W_{80}: Total moisture content in 1980, calculated from Eq. 2-4 assuming $\alpha = 1$. (wt%)

Wa_{80}: Actually surveyed total moisture content (wt%)

iii) Bulk density

Based on the survey results of "Survey of the Properties and Generation of Solid Waste", the relation between bulk density and total moisture content was formulated into the equation shown below.

$$\left.\begin{aligned} \gamma &= \alpha\hat{\gamma} \\ \hat{\gamma} &= -0.03914 + 0.005794W \\ \alpha &= \gamma_a(80)/\gamma(80) \end{aligned}\right\} \text{(Eq.2-5)}$$

where, γ: bulk density (kg/L)

W: moisture content (from Eq.2-4) (wt%)

α: coefficient of adjustment

$\gamma_a(80)$: actually examined value of bulk density in 1980

$\hat{\gamma}(80)$: calculated value of bulk density in 1980 by the second equation in Eq. 2-5.

(2) Results of the forecast

Utilizing the estimation results of physical composition on dry basis (ref. section 2.3.1) and the forecast method above in paragraph (1), forecasts were made concerning physical composition on a wet basis, moisture content and bulk density. The forecast figures are shown in Table 2.18.

Table 2.18 Forecast of future physical composition (on wet weight basis), moisture content and bulk density

Physical composition (wt% on wet basis)		Year				
		1980	1985	1990	1995	2000
1. Combustibles		83.9	84.0	84.1	84.0	83.9
Breakdown	Paper	18.3	19.6	20.8	21.5	22.1
	Textile	3.6	3.9	4.2	4.3	4.4
	Garbage	29.9	29.1	28.3	28.0	27.6
	Grass and Wood	23.2	21.8	20.7	19.9	19.4
	Plastics	7.5	8.2	8.7	9.0	9.2
	Rubber & Leather	1.4	1.4	1.4	1.3	1.2
2. Incombustibles		10.3	10.1	9.9	10.0	10.0
Breakdown	Ferrous metal	2.0	2.0	2.1	2.1	2.2
	Non-ferrous metal	0.1	0.1	0.1	0.1	0.1
	Glass	2.4	2.5	2.5	2.6	2.6
	Stones & Ceramics	2.4	2.3	2.1	2.1	2.0
	Bones, Shells & Crusts	3.2	3.1	3.0	3.0	3.0
	Dry cells	0.2	0.1	0.1	0.1	0.1
3. Miscellaneous		5.8	5.9	6.0	6.0	6.1
4. Total		100.0	100.0	100.0	100.0	100.0
Moisture content(wt%)		57.1	56.5	56.0	55.7	55.4
Bulk density (in reception pit)		0.29	0.29	0.28	0.28	0.28

Estimated by the Study team.

2.3.3 Forecast of the future solid waste chemical composition

(1) Forecast of the future element composition

The future element composition (C, H, O, N, S, Cl, ash) of combustibles (including miscellaneous item) was forecast.

Element composition of each solid waste component was obtained from results of "Survey of the Properties and Generation of Solid Waste". Applying the future physical composition, the element composition of combustibles (incl. misc. items) was obtained from the equation shown below.

$$e_j = \alpha_j \Sigma_i C_i g_{ij} / \Sigma_i C_i \qquad \text{(Eq. 2-6)}$$

where, e_j : Share of element 'j' in combustibles (wt%, dry basis)

C_i : Share of physical component 'i' in dried solid waste (wt%, dry basis)

g_{ij} : A share of element 'j' in physical component 'i' (wt%, dry basis)

α_j : Coefficient of adjustment

"g_{ij}" determined from analysis of reception pit waste is shown in Appendix 2.21.

α_j is a coefficient of adjustment to make the actually obtained value e_j be the same as the estimated value e'_j by the equation $e'_j = \Sigma_i C_i g_{ij} / \Sigma_i C_i$ of solid waste in 1980.

Future element composition was forecast by using the future physical composition and the element composition forecast by Eq. 2-6.

The forecast value is shown in Table 2.19.

(2) Three major components and calorific value

i) Forecasting method

a. Ash content in dry solid waste

Ash content in dry solid waste was obtained as a sum of ash content in combustibles (including miscellaneous items) and incombustibles. Accordingly,

$$A = Ic + (100 - Ic)a/100 \qquad \text{(Eq. 2-7)}$$

where, A : Ash content in dry solid waste (wt%, dry basis)

Ic : Share of incombustibles in dry solid waste (wt%, dry basis)

a : Share of ash in combustibles (incl. mis. items) (wt%, dry basis)

Table 2.19 Forecast of chemical properties

Item		Year				
		1980	1985	1990	1995	2000
Three major components (wt%) :						
Moisture content		57.1	56.5	56.0	55.7	55.4
Ash content		15.7	15.6	15.6	15.6	15.7
Combustibles content		27.2	27.9	28.4	28.7	28.9
Total		100.0	100.0	100.0	100.0	100.0
Elemental composition of wet solid waste (wt% on wet waste basis)	C	15.00	15.40	15.70	15.90	16.07
	H	2.26	2.34	2.39	2.43	2.45
	N	0.35	0.35	0.34	0.34	0.34
	O	9.32	9.48	9.61	9.68	9.74
	S	0.06	0.06	0.06	0.06	0.06
	Cℓ	0.23	0.24	0.25	0.25	0.26
	Total	27.22	27.90	28.40	28.70	28.92
Lower calorific value (kcal/kg, wet basis)		1,130	1,190	1,230	1,260	1,280

Estimated by the Study team.

Note : Figures of the year 1980 were obtained from Survey of Properties and Generation of Solid Waste carried out in 1979 and 1981.

b. Three major components of solid waste

The three components in wet waste were determined by the following equations:

$$A' = A(100-W)/100 \quad \text{(Eq. 2-8)}$$
$$B = 100 - (A' + W) \quad \text{(Eq. 2-9)}$$

Where, A' : Ash content in wet solid waste (wt%)

B : Combustibles in wet solid waste (wt%)

W : Moisture content in wet solid waste (wt%) (Eq. 2-6)

A : Ash content in dry solid waste (wt%, dry basis) (Eq. 2-7)

c. Calorific value

The lower calorific value of wet solid waste is forecast by the following equation. (Note: for the formulation of the equation, refer to Appendix 2.22)

$$H_u = \alpha \frac{100-W}{10,000} \sum_i (H_{oi} - 5,400h_i) C_i - 6W \qquad \text{(Eq. 2-10)}$$

where, H_u : Lower calorific value of 1 kg of wet solid waste (kcal/kg)

W : Moisture content in wet solid waste (wt%) (Eq. 2-6)

H_{oi} : Higher calorific value of solid waste component 'i' (kcal/kg, dry basis)

h_i : Share of hydrogen in solid waste component 'i' (wt%, dry basis)

C_i : Share of solid waste component 'i' in dry solid waste (wt%, dry basis)

α : Coefficient of adjustment to make the actually measured lower calorific value H_u the same as the calculated value

ii) Results of the forecast

Results of the forecast of three major components and calorific values are shown in the previous Table 2.19.

Chapter 3 RECOMMENDATION OF SHORT-TERM INPROVEMENT PLAN

CHAPTER 3 RECOMMENDATION OF SHORT-TERM IMPROVEMENT PLAN

3.1 *Summary of Short-term Improvement Items*

List of Short-term Improvement Items

	No.	Code	Caption	Outline	page
Discharge and collection	1	I(1)	Solid waste container	Use of containers stipulated in BMA ordinance	3-11
	2	I(2)	Discharge of solid waste at designated hour and place	Discharge of solid waste in the specified container at designated date and hour at designated place	3-12
	3	S(1)	Control of solid waste discharged from apartments and housing estates, and administrative guidance for construction of these buildings	Guidance of installation of solid waste storage depots, control of use of dust chutes and implementation of approval system for solid waste storage and disposal plan	3-12
	4	I(3)	Storage of solid waste in large markets	Adoption of hauled container collection system	3-13
	5	S(2)	Purchase of hauled-type containers	The costs should be borne by beneficiary businesses as a rule	3-14
	6	S(3)	Self-disposal of hospital waste by incineration (large hospitals)	Imposition of responsibility on hospitals for installation of incinerators	3-14
	7	I(4)	Discharge and collection of hospital waste discharged from medium and small hospital	Storage of hospital waste in exclusive-use waste bags at the exclusive-use waste depot in the hospitals, and collection by the city authorities	3-15
	8	S(4)	Storage of solid waste generated in hotels, department stores, etc.	Purchase of hauled-type containers at the expense of the beneficiaries as a rule	3-16
	9	S(5)	Storage and collection of slum waste	Free-of-charge collection applying hauled container collection system	3-16
	10	S(6)	Equalization of work volume of collection workers	Preparation of the work manual Introduction of swing crew system	3-18
	11	I(5)	Standardization of collection frequency, and collection according to work plan	Establishment of collection tour program in order to realize collection (code I(2)) at designated date, hour and place	3-19

	No.	Code	Caption	Outline	Page
Discharge and collection	12	I(6)	Guidance for citizen cooperation	Guidance and education of citizen by surveillants through dissemination, public relations, etc.	3-19
	13	R(1)	Tipping	Correction of tipping habit in the long run. Restriction of inequitable collection service caused by tipping	3-20
	14	R(2)	Retrieval of reutilizable materials		3-21
	15	S(7)	Expansion of road cleaning areas by BOS	Mechanization of manual cleaning in traffic-congested areas (traffic lanes)	3-23
	16	R(3)	Expansion of solid waste collection areas in Khlongs	Cleaning of large Khlongs	3-23
	17	I(7)	Solid waste collection by boats from areas along Khlongs	Collection of solid waste in areas to which access from the land is difficult	3-24
	18	S(8)	Rationalization of solid waste collection by boats from areas along Khlongs	Collection of solid waste from Khlongs at designated day and hour from solid waste depots located on the banks of Khlongs	3-24
Transportation	19	I(8)	Transfer of the ownership of spare trucks	Transfer of the ownership of spare trucks from BOF to BOS in order to promote utilization	3-25
	20	I(9)	Enforcement of daily inspection by driver	Reduction of repair rate of collection trucks and prevention of accidents	3-26
	21	S(9)	Distribution of collection trucks according to the planned solid waste collection volume of each district	Distribution of collection trucks to match to collection plan and circumstances of each district	3-26
	22	R(4)	Equipment with an auxiliary loading device to 8 m^3 non-compactors	Facilitation of loading work and raise of loading efficiency	3-29

	No.	Code	Caption	Outline	Page
Transportation	23	S(10)	Stock control of spare parts for collection trucks	Solution to problems of stand-by trucks idly waiting for spare parts	3-29
	24	S(11)	To shorten idle time of collection trucks arising from breakdowns	Enforcement of periodical inspection. Implementation of minor maintenance and repair in each district. Employment of unit-replacement system	3-30
	25	R(5)	Recruitment of skilled mechanics and training of mechanics for repair and maintenance of vehicles	Establishment of education and training system. Imposition of obligation to work for the public organizations. Introduction of mechanic qualification test system	3-32
	26	R(6)	Commissioning of private contractors for collection and transport of solid waste	Promotion to commission private contractors especially to dispose of business waste	3-33
Compost plant	27	I(10)	Classification of delivered solid waste by interview	Rough classification according to nature of solid waste loaded on the collection trucks	3-42
	28	I(11)	Incineration of unsuitable waste for composting mixing with combustible waste	To increase total calories and help incineration	3-42
	29	I(12)	Drain of leachate from the reception pits	Reduction of moisture content in the raw waste to promote its fermentation	3-43
	30	S(12)	Roofing of secondary fermentation yard	Prevention of erosion of fertilizing components by rainwater	3-44
	31	S(13)	Roofing of outdoor trommel of Nong Khaem compost plant	Raise of trommel operation rate during rainy season	3-44
	32	S(14)	Installation of trommels at On-Nooch and Ram Intra compost plants	Increase of for-sale compost production capacity	3-44
	33	S(15)	Compost sales promotion measures		3-47
	34	S(16)	Additional installation of burners in the existing incinerators	Improvement of incineration capacity of hospital waste and unsuitable waste for composting	3-50

	No.	Code	Caption	Outline	Page
Compost plant	35	R(7)	Addition of new classification process	Removal of unsuitable waste for composting	3-50
	36	R(8)	New installation of incinerator used exclusively for hospital waste	Perfect disposal of hospital waste	3-51
	37	R(9)	Preparation of an operation control manual and maintenance control manual	Security of safe and stable operation of the facilities	3-51
Final disposal system	38	I(13)	Transfer of control of both Tung Kru and Bung Phrayasalum final disposal sites to BOS	Transfer of jurisdiction of both final disposal sites so as to more utilize them	3-53
	39	I(14)	Even laying and compacting of solid waste layers	Facilitation of rainwater drain. Prevention of partial ground subsidence. Maintenance of safe operation	3-53
	40	I(15)	Circulation spray of leachate during dry season	Reduction of leachate	3-54
	41	I(16)	Continuous 24-hour operation of leachate treatment system	Prevention of inactivation of activated sludge	3-55
	42	I(17)	Spray of insecticide for extermination of vermin and insects		3-55
	43	I(18)	Clarification of control territory of landfill site	Clarification of officers responsible for jurisdiction over landfill sites	3-56
	44	S(17)	Establishment of a reclaimed land utilization plan	Formulation of plans wherever possible	3-57
	45	S(18)	Pre-embanked sectional sanitary landfill method		3-57
	46	I(19)	Disposal of night soil	To be disposed of near the center of landfill to minimize negative influence to leachate	3-60
	47	R(10)	Strengthening of fire fighting system	Prevention of fire at landfill sites in the dry season	3-60

	No.	Code	Caption	Outline	Page
	48	R(11)	Installation of gas bleeding facility	Prevention of stagnation of flammable gases	3-60
Administrative system	49	I(20)	Complete collection of unpaid solid waste collection fee	Collection of unpaid collection fee reaching 6/7 of the due	3-61
	50	I(21)	Introduction of cost control system	Quantitative comprehension of the actual state of solid waste management	3-61
	51	I(22)	Complete supply of work clothes and other outfits	Measures for work safety and welfare	3-62
	52	S(19)	Weighing the total volume of incoming solid waste to compost plants and final disposal sites	Collection of basic data for control of solid waste management system	3-62
	53	S(20)	Collection, centralized control, analysis and effective use of fundamental data and information	Control of work records. Analysis of solid waste components. Compost tests. Measurement of environmental pollution items	3-62
	54	S(21)	Training of workers	To improve morale and give basic knowledge	3-63
	55	S(22)	Installation of shower facilities	For the workers' sanitary welfare	3-63
	56	S(23)	Implementation of measures for labor safety and health		3-63
	57	S(24)	Expansion of the present duty of surveillants	Guidance of citizen, surveillance against illegal disposal, supervision and guidance of collection work, guidance of business waste disposal, response to complaints from citizen, and public relation activities	3-63
	58	R(12)	Establishment of the solid waste management standard	Standardization of minimum function to be maintained at each stage of solid waste management	3-64
	59	R(13)	Coordination between all authorities concerned	Priority should be given to cooperation with the internal organizations in BMA	3-65

	NO.	Code	Caption	Outline	Page
Administrative system	60	R(14)	Suppression of solid waste discharge volume		3-65
	61	S(25)	Establishment of bonus system	To raise the morale of workers	3-66
	62	S(26)	Introduction of merit certification system for advancement of workers	To provide the workers with opportunities to be promoted from worker to general administrative employee	3-67
	63	S(27)	Transfer of control of trommel from BOF to BOS	To separate compost sales function from the production function in order to improve compost quality and to promote compost sales	3-67
	64	S(28)	Centralization of authority of sanitation administration	To strengthen control power of BOS for effective execution of sanitation administration	3-67
Measures during flood	65	I(23)	Storage of solid waste during floods	Use of tightly sealed containers. Set-up of temporary solid waste depots in the flooded area	3-72
	66	I(24)	Priority arrangement of diesel collection trucks to flooded areas	Diesel trucks which are more resistant to water than gasoline trucks should be intensively assigned to the flooded areas	3-73
	67	S(29)	Various measures to continue the collection and transportation of solid waste during floods	Preparation of the flood route maps. Installation of guide signs. Set-up of temporary solid waste stations. Collection and transport by boats. Organization of headquaters to cope with solid waste during floods	3-73

3.2 Procedure for Formulation of Short-term Improvement Plan

(1) Survey of present condition of solid waste management system in Bangkok

Based on the result of preliminary survey carried out from 1979 to 1980, the Study team performed the first field survey in Bangkok in an approximate period of 9 months from June 1980 to February 1981. The data and information used to formulate the recommendation of short-term improvement plan were obtained mainly from the results of the survey of the existing solid waste management system. Appendix 3.1 shows an outline of solid waste management system in Bangkok city. In one year period since then, social, economic and political developments in Bangkok necessitated modification of some part of the proposed solid waste management system. In order to make the short-term improvement plan more practical, the Study team has performed a series of surveys through which change of circumstances was confirmed, and has made efforts to reflect the results of the latest survey in the short-term improvement plan.

(2) List-up of short-term improvement items

Surveys of the existing solid waste management system revealed various problems. Theoretically, it may be the best way to set up countermeasures to solve all of the problems. Practically, however, there is little hope to realize the recommended plan, no matter how good it is, if it exceeds BMA's administrative and financial capacities or if it does not agree with the policy of BMA.

Therefore, the Study team set up the following 3 guidelines for formulation of short-term improvement plan,

- The plan should match to BMA's financial ability, and the plan should produce reasonable benefit toward the investment.
- The plan should agree with the policy "environment protection" and "resources recovery" which is the fundamental idea of the Study team as well as a part of BMA's policy.
- The plan should conform to the administrative circumstances of BMA.

Short-term improvement items formulated in accordance with the above guidelines were summarized in a list for the further study mentioned below.

(3) Selection of short-term improvement items

The items listed above were further examined and screened from the aspects of practicability and reasonability as the improvement plan, applying the selection criteria described below;

i) Whether or not the short-term improvement items fit with the existing solid waste management system,

ii) Whether or not the items can be realized in 5 years,

iii) Whether or not the items can be realized with BMA's financial capacity.

iv) Whether or not the items can be implemented with administrative capacity of BMA.

v) Whether or not the items coordinate with the long-term Master Plan.

The items which satisfying the above criteria were selected and determined as the final short-term improvement items.

(4) Ranking of short-term improvement items by urgency of implementation

The short-term improvement items were classified into ranks according to their respective urgency of implementation.

To judgement of urgency, the following criteria were set up and applied.

i) Necessity of improvement

ii) Facility of improvement

iii) Magnitude of effect of improvement

iv) Magnitude of financial burden

Applying the above criteria, each improvement item was classified into one of the following categories by degree of urgency for implementation.

i) Items to be implemented immediately (I)

- Items which require BMA no or very small financing burden or items which have large necessity of implementation even though require some significant expense.
- Items which produce obvious improvement effect.
- Items which are implementable from both technical and administrative viewpoints.

ii) Items to be implemented in steps (S)

- Items which require preparation of the implementation program, recruitment of personnel and budget raising in advance of the implementation.

iii) Other items, implementation of which is recommendable (R)

- Implementation of the items should be decided by BMA taking their administrative and financial circumstances into considerations.

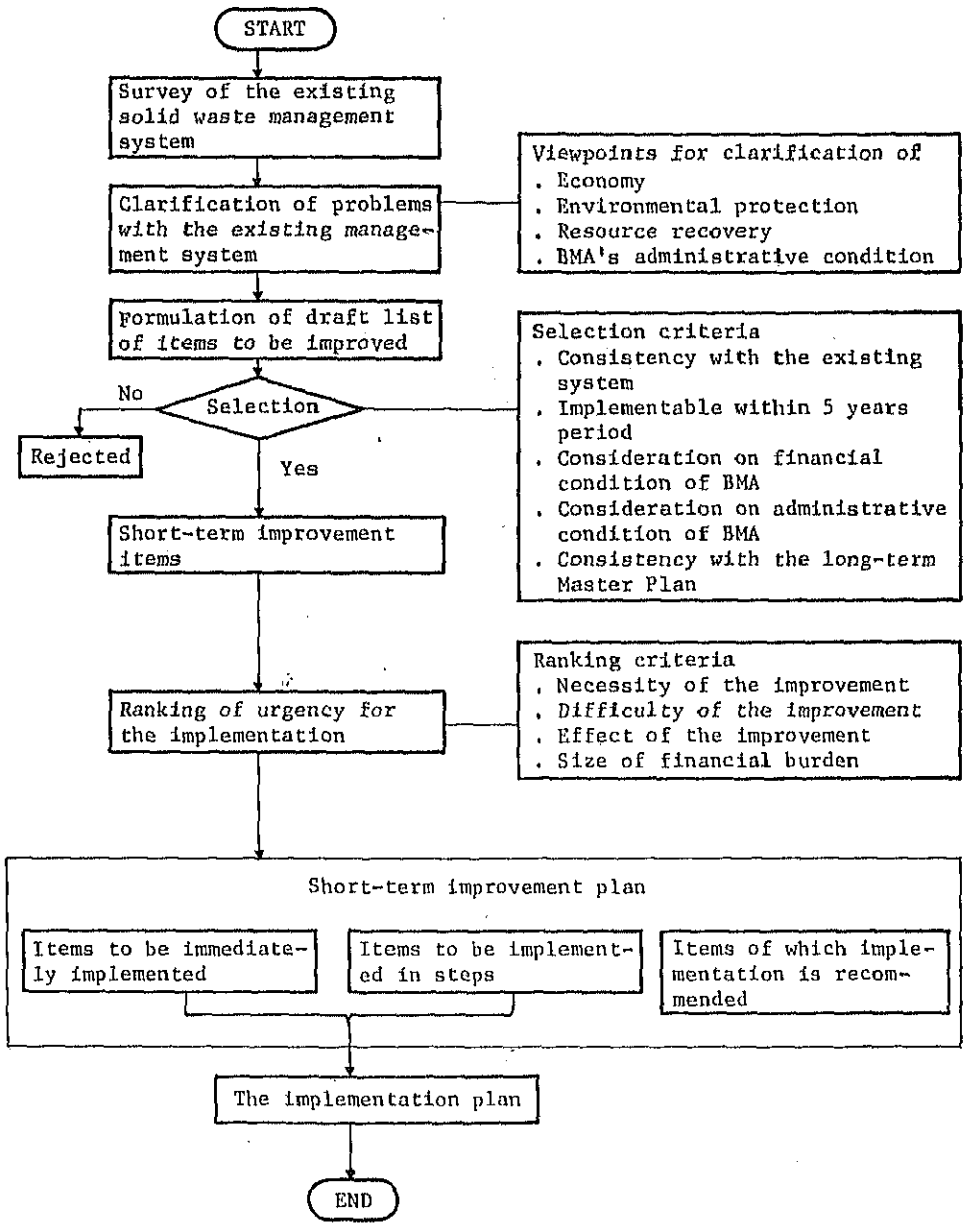
(5) Establishment and presentation of short-term improvement plan

The items which had been selected and ranked in accordance with

the aforementioned procedure were divided into six groups of functional elements. They are solid waste collection (including discharge and storage), transport, compositing, final disposal, and collection and transport during floods. Collecting all these items, the short-term improvement plan was formulated which is introduced hereafter. Fig. 3.1 shows the work flow for formulation of the short-term improvement plan.

The short-term improvement plan is assumed to be implemented in the period from fiscal 1982 to 1987.

Fig. 3.1 Work flow for recommendation of short-term improvement plan



3.3 Short-term Improvement Plan

3.3.1 Collection system

(1) Problems concerning citizen cooperation

Since each process of collection, transport, intermediate treatment and final disposal is conducted under the responsibility of BMA, it is not impossible to solve problems about solid waste management and improve the situation by BMA's efforts. On the other hand, solid waste discharge is made by citizens who are not under the direct control of the authority. Hence, some problems related to discharge contain matters which cannot be solved within the power given to BMA regardless of its effort. The habit of slum residents to dispose of solid waste under their floors, for example, will never be changed only by means of revising the regulations, strengthening the penal regulations or performing strict surveillance. For the slum residents who are accustomed to dispose of solid waste under their floors as a part of daily habits and have no concern with it, it will be troublesome to have them bring their solid waste to a designated place even if a special favor is granted them to enjoy free-of-charge solid waste collection.

It may be physically possible to increase the number of collection workers and have them tour every corner of the slum area for solid waste collection. If such a system is employed, it will not only result in remarkable increase of costs but also encourage illegal solid waste disposal by the slum residents and invite a negative result. In short, how to maintain the living environment depends upon consciousness of the environment by residents who live in the slum and work there, or more frankly, by their living standard. Improvement of environment is closely related to the improvement of living standard.

Most problems related to discharge of solid waste are caused by low environmental conciousness and lack of responsibility by people who cause such problem. There is no way for final solution of the problems other than the reformation of the consciousness of the people through education and welfare. Therefore, solid waste problems cannot be finalized if they are manipulated only from the standpoint of solid waste management. The concerned authorities are seriously requested to clarify what the overall administration should do in order to reform citizens' conscious about their living environment and to encourage their desire for environmental improvement. Among them, BOS is particularly requested to make its role in the overall administration clear and perform it step by step. This approach may seem roundabout to the goal but, it is the quickest way to solve solid waste problems. Public relations and guidance of citizens mentioned in the short-term improvement plan are roles to be performed by the sanitation administration on the assumption that respective administration achieves its function to improve the living standard of citizens; therefore, if sanitation administration only makes a small effort in public relations or guidance of residents, a satisfactory effect cannot be expected. Many of the problems related to discharge of solid waste are social problems which may not be easily solved in a short time by a single sanitation administration unless overall administration sectors make their utmost efforts to solve the problems.

Among the steps which should be taken by the overall administration, the items directly relating to the sanitation administration such

as administrative assistance, service and control were selected and improved methods are proposed in this short-term improvement plan.

(2) Discharge of solid waste

Storage and collection

Currently, the most popular solid waste containers used in Bangkok are bamboo baskets. In addition, various containers such as plastic bags and metal drums are used arbitrarily. The Bangkok Metropolitan Administration Ordinance imposes the obligation upon citizens to use a sealed-type solid waste container with a lid. However, this regulation is seldom observed because:

- The regulation is not thoroughly known by citizen
- Bamboo baskets are cheap and easily obtainable everywhere
- There are a few cases of actual punishment of people who violated the ordinance

What is more, bamboo baskets are so strong and flexible by nature that they are able to bear rough handling or tight packing with solid waste; therefore, they are widely used not only for solid waste containers but also for many other purposes. Bamboo baskets are irreplaceable containers for some applications because of their good air and water permeability; however, this merit becomes a disadvantage when they are used as containers for solid waste.

Bamboo baskets are inadequate containers to store solid waste indoors as they cannot prevent leakage of rank ordour and leachate. Consequently, people leave bamboo baskets in front of their houses. People pile solid waste from their houses in bamboo baskets left outdoors, and when bamboo baskets are filled with solid waste, they leave the excess solid waste around bamboo baskets. As a result, solid waste is scattered around whole neighborhood areas. What is worse, people are apt to leave types of solid waste outdoors that could be stored indoors in order not to miss the chance of an irregular solid waste collection.

On the other hand, the collection workers have to collect solid waste discharged in front of each house one by one and pick up scattered waste on pavement. Solid waste discharged in front of houses to which collection truck is easily accessible can be loaded directly onto collection truck but, in the case of solid waste discharged from houses along narrow backstreets which collection trucks cannot access, collection workers go around to each house pushing pushcarts, transfer solid waste from bamboo baskets placed in front of houses into their own bamboo baskets, put bamboo baskets on the pushcarts and convey them to a spot where collection truck waits; such work is very laborious. In order to improve such condition, the following recommendations are proposed.

I(1) Solid waste container

Guidance and control should be strengthened to encourage use of sealed-type containers with a lid as specified in the BMA Ordinance on the Disposal of Refuse, Waste and Filth.

As the spread of plastic products is remarkable and plastic molding can be done locally in Thailand, reduction of the price of plastic solid waste containers is expectable if the standardized plastic solid waste containers are produced on a massproduction basis. For the low income household, certain aid should be given such as loan of waste container free of charge or subsidy for purchase of solid waste container.

I(2) Discharge of solid waste at designated hour and place

Households and others which discharge small amounts of solid waste should carry their own solid waste in a specified container to a designated depot at a designated hour of designated day. After collection, the dischargers take empitied waste containers back home. In loading of solid waste at depot, solid waste is directly dumped into collection truck from the discharger's container. An appropriate collection method should be selected according to circumstances of each area such as door-to-door, station and container system. It is desirable to set up solid waste depots (stations) at intervals of every 20 meters.

To perform solid waste collection at a designated hour of designated day, the collection system should be changed from current unscheduled and irregular system to scheduled and regular system. For this purpose, a detailed work plan for solid waste collection should be set up and put into operation.

By adoption of station system, the work volume of collection workers will be reduced and the collection efficiency will also be much improved. As a result, residents will be released from an unpleasant life surrounded by waste.

Therefore, the existing door-to-door collection system should be changed to the station system wherever possible. For the households which are remote from solid waste depot, a small-size depot for pushcart collection may be provided for their convenience. As for solid waste collection and transport, it may be worthwhile to consider introduction of smaller size collection trucks.

Many large buildings, apartments and offices are equipped with dust chute. The dust chute of these buildings is generally poorly controlled. The dust chute is used as a solid waste dumping pit so that solid waste overflows from the outlet gate of the dust chute and is piled up and scattered around the gate. Some apartments are equipped with neither dust chute nor solid waste depot, that forces the residents to illegally dispose of solid waste.

S(1) Control of solid waste discharged from apartments and housing estates, and administrative guidance for construction of these buildings

In the case of buildings equipped with dust chutes, the responsibility of the owners for control of dust chute should be made clear. Should solid waste overflow or be scattered and this be found to be caused by insufficient maintenance of dust chute, strict measures should be applied according to the Ordinance. On the other hand, the administrative side is also requested to take proper measures in order to avoid overflow by

means of, for example, increase of solid waste collection frequency.

The apartments which are not equipped with proper solid waste storage should be guided to install solid waste container depots. Preparing for construction of new apartments or housing estates, establishment of a new legal system needs to be implemented so it will be required to forecast the solid waste volume to be discharged from the structure and present a disposal plan to the concerned authority who must examine the documents for approval. The approval should be regarded as one of the indispensable conditions prior to engaging in construction. The sanitation administration would prepare their solid waste collection program according to the plan submitted.

i) Market waste

There are about 200 markets in Bangkok city, from which 135 tons per day of solid waste is estimated to be discharged.

The stall keepers dump their solid waste directly into depot without using a container. In many markets, solid waste depots are installed in several spots where collection trucks cannot approach. Solid waste stored in depot is transferred into bamboo baskets and conveyed on pushcart to collection truck by collection workers. Collection workers also clean the solid waste depots. Cleaning of solid waste around stalls is done by road sweepers, which increase work volume of road sweepers and invites waste of labor.

I(3) Storage of solid waste in large markets

For large markets, use of hauled-type containers (ref. Appendix 4.2) is recommended.

Hauled-type containers filled up with solid waste are collected by arm roll trucks.

Hauled-type containers should be placed at the spots in a market where arm roll trucks can easily access. The unit price of the hauled-type container (10 m^3) is about 80,000 Baht. Although this expense should be borne by enterprisers who benefit from it as a rule, it may be difficult to evenly impose such purchase cost on all businesses since the price is high. Therefore, the administrative side is requested to provide hauled-type containers at places of public interest and areas where introduction of hauled-type containers is urgently needed. This will be of use for the purpose of public relations, too. Incidentally, the price of one arm roll truck is approximately 500,000 Baht.

In small markets to which application of hauled-type containers is too expensive, a roofed solid waste container depot should be constructed, into which the stall-keepers carry their own solid waste in the container specified in the Ordinance. The floor of the depot should be elevated to the proper height to avoid submergence during floods. Responsibility of stall-keepers in the markets should be specified in the ordinance so that they are obliged to carry their own solid waste to designated depots and clean the inside of markets by themselves.

The afore-mentioned recommendations for large markets should also be applied to Sunday markets, provided that common areas where the stall-keepers cannot assume such responsibility are cleaned by the administrative side.

S(2) Purchase of hauled-type containers

When a hauled-type container is chiefly used by a business, the cost of its purchase should be borne by the pertinent business as a rule. Nevertheless, as it will be difficult to impose responsibility to purchase hauled-type containers on businesses at their account since the price is high, the administration side is requested to examine the businesses' financial capacity, objective necessity and urgency for purchase of hauled-type containers, then take practical measures of popularization of hauled-type containers. The main sectors for introduction of hauled-type containers will be those businesses who discharge a large amount of solid waste such as hotels and department stores in addition to the large markets. When introduction of hauled-type containers is urgently needed despite financial inability to purchase it, the administrative side should take all possible measures without burdening the business side, such as free loan of hauled-type containers to businesses for a certain period until they reserve the money for the purchase, or levy of hauled-type container purchase cost combined with solid waste collection fee.

ii) Hospital waste

The volume of solid waste discharged from hospitals in Bangkok city is estimated to be approximately 40 t/d. The hospitals store the waste suspected of being contaminated by diseases and organic waste produced from surgery (referred to as hazardous hospital waste) in the black vinyl bags, and common solid waste other than the above in bamboo baskets. Some hospitals dispose of hazardous hospital waste by incineration by themselves.

For the collection of hospital waste, compactor trucks are normally used. Use of container trucks is limited for some hospitals.

Hazardous hospital waste packed in the black vinyl bags are discharged together with common waste, and the collection workers collect them without wearing specified uniform, gloves and shoes and try to retrieve utilizable materials from them. Only a few hospitals in Bangkok city are equipped with proper waste storage facilities.

S(3) Self-disposal of hospital waste by incineration (large hospital)

Large hospitals should assume responsibility for installation of incinerator and self-disposal of hazardous hospital waste.

(Phaya-Thai Hospital is already performing self-disposal by incineration.)

In spite of the above description, considering the large expenses needed for purchase of the incineration equipment, the administrative side should give administrative guidance to

hospitals taking their respective circumstance into account, and enforce self-disposal of hospital waste on hospitals which are able to install the incineration equipment. Hasty imposition of the responsibility on hospitals might incur undersirable results like incomplete disposal of hazardous hospital waste. Until a selfdisposal system for large hospitals is established, the disposal of hazardous hospital waste should follow the procedure for medium and small hospitals described below.

I(4) Discharge and collection of hospital waste discharged from medium and small hospital

Hazardous hospital waste generated in medium and small hospitals should be put in exclusive-use bags (thick vinyl bags) specified by the authorities. The bags containing hazardous hospital waste should be tightly sealed and placed in exclusive depots. Each hospital should provide a depot to be exclusively used for hazardous hospital waste other than common solid waste depot. The exclusive depot can be set in a part of common solid waste depot by dividing it into two parts by an isolation wall.

The protective outfits (uniform, gloves, etc.) should be preferentially supplied to those workers who are engaged in collection of hazardous hospital waste.

The workers should be strictly instructed to wear the prescribed outfits. The protective outfits should be disinfected periodically.

Common solid waste discharged from hospital will be coped with in the same manner as done with other business waste; that is to say, hauled-type containers will be set at large hospitals whereas roofed depots will be installed in medium and small hospitals. Common solid waste discharged from private clinics should be collected in the same manner as applied to household waste; however, empty bottles and ampules of poisonous or powerful medicines, discarded chemicals, used medical supplies and the like are not permitted to be discharged as common waste.

iii) Other business waste

The total volume of solid waste discharged from hotels, department stores and supermarkets in Bangkok city is estimated to be approximately 37 t/d, a large portion of this is hotel waste.

Among these service trade enterprises, there is a tendency to provide a small area for a solid waste storage depot. It is simply because the businesses are eager to secure a wider business area. Especially in hotels, the areas of solid waste depot are relatively small for the waste discharge volume. In addition, they dump and scatter solid waste directly into solid waste depot, that makes the depot unsanitary and use of its narrow space ineffective. The collection workers have to transfer disorderly discharged solid waste into bamboo baskets and convey it to collection truck; hence the operation efficiency is very low.

S(4) Storage of solid waste generated in hotels, department stores, etc.

Hotels and department stores which discharge a large volume of solid waste are recommended to use hauled-type containers. For these large business sectors, obligation to purchase hauled-type containers at their own expenses can be imposed. Notwithstanding, small hotels discharging small volume of solid waste and businesses which are unable to secure an adequate space for hauled containers may be exempted from the obligation provided that they install a solid waste depot with a roof. In this case also, solid waste should be packed in plastic containers and placed in the depot in good order. If the solid waste depot is too small and has no room for expansion, container shelves may be constructed on the wall of the depot so as to fully utilize the space. Surveillants are requested to supervise the construction of shelves and discharge of solid waste. To avoid increase of the work load of workers, two levels of container shelves will be made with the top shelf for lightweight containers.

iv) Slum waste

According to the survey by NHA, about 280 slums are scattered in 18 districts of Bangkok Metropolis. The number of households in slums is estimated to be about 68,000 and the total solid waste volume generated from them to be about 52 t/d. Illegal disposal of solid waste around houses or under floors has become a custom in slums, and that makes solid waste collection in slum areas extremely difficult. The problem of slum waste is problem of the slum itself and there is no drastic remedy other than execution of slum clearance by comprehensive administration. However, it should be the duty of sanitation administration to give certain aid to those who are compelled to illegally dispose of solid waste because of inability of paying the collection fee, or to permanently educate those people who are accustomed to illegal disposal owing to lack of sense of sanitation.

S(5) Storage and collection of slum waste

Collection of slum waste should be made applying hauled-type container system free-of-charge. As roads in the slums are generally too narrow to permit access of arm roll trucks, hauled-type containers will be installed at the entrance or other places in slums. Appeals to the slum inhabitants should be made for disposal of their waste into the containers. The existing container trucks should be assigned for slum waste collection. Hauled-type containers should be loaned and the collection should be made free-of-charge. The slum inhabitants have to carry solid waste generated in the slums to hauled-type containers because, as a rule, the collection workers do not enter into slums for solid waste collection. As a part of an environment protection campaign, special collection teams should be organized, which will tour around slums and show the inhabitants and effective method of environmental purification and make them aware of the importance of sanitation activities. In addition, persons who are conscious of the importance of environmental protection should be selected from the slum

inhabitants as leaders of slums to guide the slum inhabitants in solid waste management in close coordination with surveillants.

(3) Solid waste collection service

Collection equipment

Pushcarts, bamboo baskets and hooks are the main equipment used for solid waste collection. One or two pushcarts are used for a compactor and 2 or 3 pushcarts for a non-compactor.

The capacity of a bamboo basket is about 90 liters, and 10 to 30 bamboo baskets are used for each collection truck.

Loading and collection capacity onto trucks

In the case of non-compactors, 3 or 4 workers are engaged in solid waste loading work per truck. According to the results of a time-motion study made by the Study team, the loading time of non-compactor (3.02 s/kg) is 1.5 times as much as that of compactor (2.01 s/kg).

In comparison with the loading time of compactors in Bangkok with that in Tokyo (0.9 s/kg) or in Kawasaki City (1.0 s/kg), the loading time in Bangkok takes about twice as much as in Japan.

This difference is considered to be caused by retrieval of utilizable materials during collection (though such retrieval is forbidden) or use of pushcarts for long distances. The time wasted for retrieval of utilizable material is estimated to be about 100 minutes per day.

The loading bulk density of non-compactor is about 0.28 t/m^3; there is little difference between 6 m^3 trucks and 8 m^3 trucks. On the contrary, the loading bulk density of compactors varies widely. Results of the actual timing revealed that it ranges from the maximum value of 0.540 t/m^3 in Dusit district to the minimum value of 0.308 t/m^3 in Bang Khen district; an average of all districts is 0.370 t/m^3.

Solid waste collection volume per collection worker per day also varies widely by district: the largest figure among the estimated mean value by each district is 1.07 t/d·worker of Nong Chok, which is about 7 times as high as the smallest mean value (0.15 t/d·worker) of Tailing Chang. The ratio of standard loading capacity to actual loading volume of each collection truck was calculated and averaged by district.

The maximum ratio was 1.22 m^3/m^3 of Nong Chok and the minimum was 0.41 m^3/m^3 of Nong Khaem. The collection volume per day per collection truck ranges from 1.4 tons to 4.0 tons.

The surveillant system has been established to check the completed condition of collection work. The total number of surveillants as of 1979 was 246 in 24 districts.

The surveillants are usually selected from among the collection workers. The collection work plan determines the territory and the number of trips of each collection truck; the collection frequency in each collection territory is left to judgement of workers in charge. Solid waste collection is usually carried out daily in office areas and main streets versus irregularly 2 or 3 times a week in other

districts. When uncollected solid waste increases, the collection is made on an overtime basis or using shifts. In the areas along rivers or Khlongs which collection trucks cannot access, people offer illegally dispose of solid waste by dumping it into rivers or Khlongs.

Solid waste collection rate by district ranges from 34% to 99% as shown in Fig. AP 3.6, which indicates that the collection is unbalanced by districts. The average collection rate of all districts in 1979 was estimated to be about 77%.

Since the solid waste collection is made on a fee basis for door-to-door collection and tipping to workers has become habitual, the workers are apt to give extra service to dischargers as a collateral service for the tip and such service is accepted as if it were a vested right of the dischargers. As a result, cooperation of the dischargers in solid waste collection activity is almost nil.

S(6) Equalization of work volume of collection workers

The actual loading volume of collection trucks, collection volume per truck and collection volume per worker varies conspicuously by district as mentioned above; however, it is too hasty to conclude from these facts that the numbers of collection trucks and workers assigned to each district are unbalanced compared with solid waste volume to be collected. The collection volume of collection trucks or collection workers does vary depending on the configuration of collection area and distance of transport.

Although the collection volume per worker does not always indicate the amount of work per worker, the fact that there is a seven-fold difference between the districts collecting largest volume and the smallest volume should be taken to indicate that the work volume varies considerably by district.

For equalization of the work volume, a work manual (refer to Appendix 3.2) should be formulated and, based on it, a work plan should be set up to enable the collection workers to bear an standard work volume if they perform the work in accordance with the manual and plan. In addition to this, introduction of swing crew system is desirable to prevent the imbalance in the work volume at least within the same district. In this system, the crews are not fixed on a specific collection duty area but are rotated to other duty areas in the district in turns. Therefore, the inequity of the work volume caused by differences in the collection areas can be resolved.

The area of solid waste collection in the duty area is presantly left to the worker's judgement so that in some areas solid waste collection is satisfactorily carried out whereas in other areas in the same duty area it is scarcely made. As the worker's judgement is often affected by inequitable factors such as profit from tips or preference for areas where solid waste collection is easily achievable, the Sanitation Section of each district should control the collection workers to perform equal solid waste collection in all areas in the district.

I(5) Standardization of collection frequency, and collection according to work plan

To perform solid waste collection at designated hour of designated day as described in section I(2), it is essential to maintain constant and periodic solid waste collection in each area. Even though the residents discharge solid waste at a specified depot at the designated hour of the designated day, if solid waste discharged is left there uncollected for a long time, it will produce a disagreeable living environment for residents. Collection trucks should go around to the individual depots for collection of solid waste within 2 or 3 hours after the discharge at a designated hour. To realize this objective, establishment of a detailed collection tour plan is indispensable. To this end, a collection work standard should be set up first of all and based on it, the collection manual should be prepared. Then, a collection tour plan should be formulated on the assumption that the collection work is performed according to the manual. In the initial stage of enforcement of the work plan, the work may not be performed as specified by the standards since the workers will not be experienced; therefore, it is recommended to give the workers some allowance in time (approximately 1.5 times greater than the standard at the initial stage). However, the time should be standardized in the initial stage, and then reduced gradually to the specified time.

I(6) *Guidance for citizen cooperation*

Maybe because of their strong consciousness that they are tipping collection workers in addition to solid waste collection fee, the amount of citizen cooperation in solid waste collection is very low. Citizens do not clean up solid waste scattered in front of their houses but leave it for collection workers to get. Enlightenment of citizens is difficult because they have no habit of environmental protection, and have contempt for sanitation work. Nevertheless, the objectives of sanitation administration should not be confined to simple collection and disposal of the solid waste, but extended to improvement of the behavior of citizens through guidance and education.

Surveillants and collection workers should appeal to citizens to discharge solid waste at a specified place using a specified method. Collection workers would be responsible for collection of solid waste discharged in the specified place using the specified method. A notice should be made saying that the dischargers' obligation to clean solid waste in front of their stores or houses should be formally contracted by means of a bill or the like. If they do not obey, it may be unavoidable to take punitive action against the offenders such as temporary suspension of collection of illegally discharged solid waste.

In order to obtain citizen cooperation, however, long and continuous guidance is needed. Application of direct sanctions without this effort must be avoided. The first measure to be taken should be to thoroughly educate citizens about what they have to do for protection and maintainance of their living

environment; in other words, how to store and discharge solid waste they generate. For this purpose, public relations activities such as distribution of pamphlets should be fully utilized.

R(1) Tipping

Tipping of road sweepers and collection workers has become habitual. Together with income from retrieval of utilizable materials, tips share a large portion of the worker's income. Tips are great incentive for workers who are engaged in the collection work which is socially repugnant. Although they are assured by their salaries to maintain their living without any additional income, the level of their salaries is low and the additional income actually supports their living. The dischargers also have a reason why they cannot discontinue the habit of tipping: because they derive some benefit. Even in the case when solid waste is not supposed to be collected by the normal collection service because it lies far away from the collection route, for instance, collection workers still collect it for the tip. Tips are often given with the positive intention of the dischargers and collection workers offering corresponding service.

In a sense, tipping can be said to play the role of a lubricant which offsets deficiency of present solid waste management system. Of course, this does not mean that the habits tipping and retrieval of utilizable materials can be approved. These habits are simply a social phenomenon which will disappear when those who are involved in such practices devine no benefits from them.

Therefore, if only suppressive control is made on collection workers without consideration of their social status and salary level, no better results can be expected. Before calling for prohibition of tipping and retrieval of utilizable materials, effort should be made to establish a social system and environment where such a habit and practice can be restricted without difficulty. Since the habit of tipping is socially accepted as a good custom in Thailand, it is difficult to restrict it by regulations. Needless to say, if people who are engaged in public service earn additional income through their service beside their salaries, this is considered to be illegal. Therefore, it is up to the authorities' judgement whether or not they prosecute offenders.

As far as solid waste management system is concerned, the problem of tipping cause idleness and partiality in the collection service. The dischargers giving tips receive excessive service and, as a result, the level of service for other dischargers is lowered. To improve the situation, efforts should be made to maintain the standard and equity of collection work by carrying out the work in accordance with a work manual and detailed collection plan described in I(5). If total volume solid waste collection from all areas is realized, the inequity by tipping will finally be solved and the dischargers will not have to give tips to the workers. Presently in some areas, however, even a normal level of collection service is not performed by

the workers if they are not given tips; or in other areas, the inhabitants consider tipping as a matter of obligation. For these areas, surveillance by surveillants should be strengthened and, at the same time, public relations should be made to make the dischargers fully aware that no money other than regular collection fee is required for the collection service.

R(2) Retrieval of reutilizable materials

From the aspect of recycle of resources, the retrieval of reutilizable materials is desirable. Nevertheless, the fact that the collection workers earn an illegal income beside regular salaries by private retrieval of material during their duty hours is a conflict of interest and that one collection worker is wasting approximately 100 minutes per day for retrieval of utilizable materials is another obstructive problem to operation of solid waste management system. The problems cannot be limited to these two points. The reutilizable materials are mainly retrieved by the collection workers at the spot of solid waste collection but, in addition to this, they often stop the collection trucks in other places on the way of solid waste transport to retrieve the utilizable materials. Such act is not only an unpleasant scene to the eyes of third parties, but also causes a conflict that the employees of sanitation authority promote environmental pollution by means of scattering collected solid waste, dripping leachate, or emitting rank odor. More serious problem is that the retrieved materials are sold to junk dealers and reused without any control at all. Although the actual state of these acts is difficult to reveal since they are illegally done, the retrieved materials are considered to be reused without sufficient treatment, so that there will be the possibility of infection of disease or spread of contamination.

Like tipping, the retrieval of reutilizable materials is also a social problem which cannot be uprooted simply by strengthening control or by setting up a detailed work plan so as to limit the collection workers time for retrieval of the utilizable materials. If too strict time limitation is imposed on the collection workers, it will make the workers reluctant to perform the main collection work or give the impression of extra work requirements.

The retrieval of utilizable material itself is not a crime, but a basic policy to prohibit the retrieval of reutilizable materials by the collection workers should be implemented since it is forbidden by law for the public service personnel.

Judging from the present circumstances that income from the retrieval of utilizable materials makes up for a considerable portion of their living expenses, this problem will never be solved by suppressing the workers from the standpoints of legality or management. For the true solution, the income and social position of workers must be improved so that retrieval of reutilizable materials is not so attractive for them. Until then, adoption of tentative and compromising measures may be needed to solve urgent and important subjects one by one. One of the positive measures is to allow collection workers spare time for retrieval of reutilizable materials at a specified place in the collection work process.

The sanitation authority could request junk dealers to take proper measures for acceptance of retrieved reutilizable materials and for disinfection and sterilization of them to assure sanitation. Implementation of the measures should be made under supervision of the sanitation authority. The specified place may be provided in the site of solid waste treatment and disposal facilities. Starting from these tentative measures, modification should be made as necessary in conformance with improvement in the economic condition of collection workers. When their sense of duty reaches a certain level, a measure aiming at psychological effect such as a commendation system, for example, will produce a large effect. An example of the above system is to reward the worker who has performed the work as specified in the work plan. Under the present circumstances where additional income from tips and retrieval of reutilizable materials amounts to several times the regular income, it is practically impossible to pay the collection workers the equivalent money to the additional income as compensation to let them discontinue such as illegal act.

When the benefit of retrieval of reutilizable materials is relatively decreased with increase of income of collection workers, a bonus system such as an incentive wage for good attendance which bring them a profit will become effective. At the same time, establishment of a merit system should be considered as one of effective means. In the system, attitude of workers is evaluated in details and its results are reflected in the wage increase evaluation, so that there is a large difference in wage between the workers who are faithfull to their duty and who are not. In short, retrieval of reutilizable materials is not such an easy problem that can be solved in a short time. The best way is to implement improvements step by step which can be accepted by social, economic and legal circumstances of the time.

(4) Cleaning of public areas

i) Road cleaning

Road cleaning is performed by BOS and the Sanitation Section of each district. The mechanical road cleaning is made by BOS and the manual cleaning by the Sanitation Section of each district.

BOS cleans the main roads in the city center which extend for a distance of approximately 198 kilometers (as of fiscal 1979) with 91 workers, 7 road cleaning trucks, and 15 water sprinkler trucks.

The sanitation section of each district cleans roads other than those under the jurisdiction of BOS. The total road cleaning area for 24 districts is approximately 1,560,000 square meters, for which 2,762 road sweepers in total (forming teams, each consisting of 2 or 3 workers) are engaged in cleaning work using a bamboo broom. The duty area of a road sweeper per day is approximately 8,000 square meters in densely populated areas, and 12,000 to 15,000 square meters in sparsely populated areas.

ii) Solid waste collection from rivers and Khlongs

Solid waste collection from rivers and Khlongs is under the jurisdiction of BSD (the Bureau of Sewage and Drainage). BSD has 15 boats and 69 workers, with which, according to a 4-month record in 1980, 2,700 m^3 per month on the average of solid waste was collected from rivers and Khlongs extending for a total of 42 kilometers.

iii) Others

Cleaning of six main parks (public parks) in Bangkok city is performed by each district to which the parks belong.

Animal carcases are collected by each district and brought to BOS for incineration disposal.

According to the records, 2,629 carcases were incinerated in 1979, and 7,195 carcases in 1980.

S(7) Expansion of road cleaning areas by BOS

Although cleaning of main roads (traffic lanes) is, as a rule, under the jurisdiction of BOS which has the mechanical cleaning forces, this rule is not always observed. Sukhumvit Road, for instance, is a main street with a large traffic volume, but the cleaning of the area eastward from Soi 11 involves dangerous manual work under the jurisdiction of each district.

The situation is the same with the city center portion of Phra Ram Road and Rama VI Road. The total length of parts of the main roads which are presently excluded from the BOS's jurisdiction is estimated to be 63 kilometers. Considering the work efficiency and the safety of workers, cleaning of these areas is desirable to be undertaken by BOS.

Two more mechanical road sweepers are required by BOS for cleaning of the additional 63 kilometers (unit price is about 2.0 million Baht). So that more than 90% of the main roads in the city center can be mechanically cleaned.

R(3) Expansion of solid waste collection areas in Khlongs

Solid waste from many portions of the large Khlongs in the city center is left uncollected. Khlong Praoa and Khlong San are examples of these. In some canals like Khlong Pha Singto, solid waste is partly collected but the effect is questionable. Considering the main large Khlongs only, cleaning of main Khlongs in the city center will be nearly completed if a total length of 39 kilometers of canal area is added to the present areas for cleaning. The number of boats required for this operation is 8 to 10.

Furthermore, to increase the cleaning effect and work efficiency, the introduction of mechanical boats to be used exclusively for river cleaning is desirable. (L 12m x W 4.5m x D 1.5m. Unit price: approximately 2.8 million Baht)

Prior to the purchase, a thorough study should be made to select the suitable type which satisfies conditions of operation such as a height of bridges over a Khlong from the water surface and the distance between bridge girders.

I(7) Solid waste collection by boats from areas along Khlongs (Prevention of illegal disposal of solid waste into Khlongs)

In the old days, residents of Bangkok city settled near Khlongs and utilized them as sources of their daily water supply and waterway for transportation. Still today, people live in the congested housing areas along the Khlongs. Many slums have also resulted along the Khlongs. In these areas, it is very difficult to collect solid waste by collection trucks because of the undeveloped road conditions, and actually they are left as uncollected areas. As a result, the residents are compelled to illegally dispose of their solid waste by throwing it under the floor or into the Khlongs. Solid waste collection from Khlong as described below will be one of the measures which would alleviate such a problem.

Adequate spots along Khlongs (at intervals of approximately 20 to 30 meters) may be selected and notification to the residents should be made by means of bulletin board indicating that these spots are designated as solid waste depots.

Solid waste discharged into the depots is collected by boats, and carried on the Khlongs to the places where collection trucks can access. As the loading spots are located in densely built-up areas in many cases, solid waste is recommended to be directly transferred from boats onto collection trucks without applying a transfer station system. The use of standby collection trucks lowers transport efficiency of collection trucks, therefore, it would be better to use hauled-type containers if the circumstances permit.

This boat collection method seems inefficient because it requires a large number of laborers for loading of solid waste from depots onto boats and from boats onto collection trucks.

This method is expected to have a considerable effect on solution of three large existing problems: collection of slum waste, prevention of illegal disposal of solid waste into Khlongs and reduction of number of uncollected areas. This system also has the advantage that it can be implemented with present equipment. It is advisable to implement this method first, and then convert to the methods described below step by step.

S(8) Rationalization of solid waste collection by boats from areas along Khlongs

Solid waste collection by boats from depots along Khlongs should be performed at the designated day and hour, and the work plan should be set up based on this system.

Introduction of mechanical boats should be attempted in order to reduce difficulties in the transfer of the solid waste and to increase the work efficiency. The mechanical boats are normally large in size; therefore, the areas which allow solid waste collection from Khlongs with these boats will be less than 50% of the object areas. Solid waste collection from the remaining areas along narrow Khlongs must be made by small size manual boats.

3.3.2 Transport system

Solid waste loaded onto collection trucks is transported directly to either compost plants or the final disposal sites. Since compost plants are constructed in the yard of final disposal sites, compost rejects and incineration residue can be disposed of at the same site without secondary transportation. The collection trucks are purchased by BOF and delivered to BOS, from where they are distributed to each district. All BMA vehicles including collection trucks are repaired at the repair shop of the Mechanical Division, BOF. The total number of registered collection trucks as of January 1981 was 504, of which 427 trucks were delivered to 24 districts, 21 trucks to BOS, and 56 trucks were reserved by the Mechanical Division of BOF as spare trucks. (As of December 1981, 454 collection trucks were retained by the 24 administrative districts and 19 units by BOS. The details are shown in Table AP 3.20).

As of 1981, collection trucks in service for more than 13 years accounted for about 14% of the total number. Some of these trucks were purchased more than 20 years ago but are still in use. Presently, no criteria for retirement or replacement of collection trucks have been established. An average operating rate of spare trucks reserved by BOF is about 65% per month. Four districts Yannawa, Dusit, Phra Khanong and Bang Khen are the most frequent spare truck users, utilizing about a half of the total spare trucks as substitutes for collection trucks under repair.

In fiscal 1980, the gross number of BMA vehicles repaired in the Mechanical Division, BOF was 10,506, of which 47% (4,621 units) were collection trucks. The repair cost per collection trucks per year is as high as about 45,000 Baht which does not include the cost of collection truck repairs by subcontractors in each district. (The individual districts are said to have collection trucks repaired by subcontractors at their own discretion because of the necessity for urgent repair, however, the actual states is not clearly known.) No correlation has been noted between the age of vehicle and occurrence of breakdown but, as a result of the investigation, it was confirmed that the repair frequency for compactors was larger than that for non-compactors. The number of days required for repair of collection truck per unit per year exceeds 60. Considerable time is wasted in waiting for a supply of spare parts since the stock of spare parts is insufficient.

The BOF repair shop has about 30,000 m^2 area, where 10,000 vehicles per year are repaired. The number of skilled mechanics is insufficient as they leave the repair shop and seek employment in private companies where they can enjoy higher pay and better working conditions. This may be one of the causes of delays in repair work.

The working rate of collection trucks (rate of usable trucks) is calculated to be as low as 82%, which indicates that collection trucks retained in each district are not effectively utilized.

The cost of solid waste collection and transport is 185 Baht/m^3 in the case of BOS, or 39 Baht/m^3 in the case of 24 districts; the average of both is 44 Baht/m^3 (152 Baht/t).

I(8) Transfer of the ownership of spare trucks

At present, 56 spare trucks are reserved by BOF. Their leasing

rate is 65%. This means that nearly 20 spare trucks are not being operated, while at the same time the collection is not being satisfactorily performed in some districts due to a shortage of collection trucks. Naturally the request for spare trucks fluctuates and these 20 spare trucks are not always standing idle; however, the present condition where many spare trucks are left idle while districts suffer from short of collection trucks should be improved. As long as the ownership of spare trucks is the responsibility of BOF, spare trucks cannot be effectively used to meet the urgent requirements of each district.

Therefore, it is recommended that the ownership of spare trucks be transferred from BOF to BOS for efficient and effective utilization.

I(9) Enforcement of daily inspection by driver (Ref. Appendicies 3.3 and 3.4)

Drivers should be expected to perform the daily inspection of collection trucks by themselves (inspection before and after work). Performance of the daily inspection by drivers contributes to good maintainance of vehicles, reduction of the repair rate and also prevention of accidents caused by vehicle problems or breakdowns.

S(9) Distribution of collection trucks according to the planned solid waste collection volume of each district

At present, the collection trucks are purchased and distributed at the request of districts; the number of the required collection trucks is calculated by the respective districts based on various criteria. As a result, the number of distributed collection trucks is not always proportional to solid waste collection volume: some administrative districts have some idle collection trucks while other districts suffer from a shortage of collection trucks.

In principle, the number of collection trucks to be distributed to each district should be determined based on the forecast solid waste discharge volume and planned collection volume of the respective administrative districts, taking into consideration the transport distance, collection territories and work efficiency for each of the respective district.

Based on the forecast discharge volume and planned collection rate estimated in Chapter 2, the collection trucks and spare trucks distribution plans for 1983 to 1987 were tentatively drafted as shown in Tables 3.1 and 3.2 respectively. Conditions for each district were not considered in the formulation of this table.

The vehicle purchase plan is established in accordance with the collection trucks distribution plan. In formulating the vehicle purchase plan, those vehicles which are old or low in work efficiency and require a large amount of maintenance and repair cost (regardless of their age) should be excluded from the vehicle distribution plan or replaced with a new one.

Table 3.1 Required number of collection trucks and the purchase plan

Name of district	Number of trucks owned	Number of collection trucks to be newly purchased (based on the planned collection volume)					Fiscal 1987
	Aug. '81	Figures to be added to number of collection trucks as of 1981					Distribution plan
		Fiscal 1983	1984	1985	1986	1987	
Phra Nakhon	35						35
Pom Prap	23						23
Phathum Wan	27	1	2	3	4	6	33
Sam Phan Thawong	15						15
Bang Rak	21	1	1	2	2	3	24
Yannawa	34	3	7	11	15	20	54
Dusit	37	4	9	14	19	25	62
Phayathai	33	3	7	10	14	18	51
Huai Khwang	17	1	2	3	5	6	23
Phra Khanong	44	5	10	15	20	26	70
Bang Khen	27	0	1	1	2	2	29
Bang Kapi	17	1	2	4	6	9	26
Nong Chok	3						3
Minburi	7						7
Lat Krabang	4						4
Thonburi	18	1	2	2	3	4	22
Khlong San	14						14
Bangkok Noi	21	3	6	9	12	15	36
Bangkok Yai	9			1	1	1	10
Bang Khun Tian	13			1	1	1	14
Phasi Charoen	13						13
Rat Burana	16						16
Taling Chan	3		1	1	1	1	4
Nong Khaem	3						3
GCD, DOPC	19		1	1	1	1	20
Total	473	23	51	78	106	138	611
No. of increase		23	28	27	28	32	
To be retired		4	4	4	4	4	
To be purchased		27	32	31	32	36	158
Required		496	524	551	579	611	

In Japan, the retirement of vehicles is standardized according to the service life span; but there is another method to fix the limit of the service life based on mileage, fuel consumption, repair cost, and so forth.

In Thailand, the Ministry of Communication has also formulated the standard service life of vehicles. According to it, the life span of collection trucks is specified as 13 years. In Thailand where the price of vehicles is relatively high so that the value of vehicles is different from that in industrially advanced nations, a vehicle control policy should be established based on the assumption that vehicles are operated by the same users until they become no longer usable nor operable on a commercial basis. For collection trucks, it is recommended that the time of retirement be determined based on 3 factors: operating rate, operation cost and relation between forecast repair cost and residual value. Since the annual mileage for collection trucks is lower and their working condition is better than that of inter-city trucks or construction site dump trucks, it is possible to use the collection trucks in good condition for more than 13 years.

The vehicles to be purchased new should be mainly compactors. Compactors have higher performance in operation and higher efficiency in transport than non-compactors. Therefore, theoretically, an increase in the number of compactors should

Table 3.2 Number of spare trucks

Number of spare trucks presently owned : 56

Type of spare trucks to be newly purchased : Dump truck - 10 m^3

Spare trucks reserve rate (Fiscal 1979 12.5%) : 12.5%

Rate of breakdown (Fiscal 1980) : 18%

Fiscal year	Planned number of trucks under operation	Spare truck reserve rate (%)	Number of spare truck	Spare truck to be retired	Spare truck to be purchased
1983	496	18	89	3	36
1984	524	18	94	3	8
1985	551	18	99	3	8
1986	579	18	104	3	8
1987	611	18	110	3	9
Total (5 years)	—	—	—	—	69

Note: Spare truck reserve rate is planned to be reduced by 1% every year from fiscal 1988 and to reach 5% in the year 2000.

proportionally increase the collection efficiency. As a matter of fact, however, the collection efficiency may not be improved as much as expected if expensive compactors are used in districts where collection volume per truck is low by nature. It should be lowered in the districts which have a smaller number of collection trucks since difficulties peculiar to compactors cause idle time for repairs. Although the frequent breakdown of compactors is not a problem to be discussed here, as long as the problem exists, it should be taken into consideration when the types of collection trucks are selected.

It is recommended that the type of collection trucks be selected according to the conditions in each administrative district. For the central districts where solid waste collection volume is large and spare trucks can be easily utilized, intensive distribution of compactors is recommended, whereas noncompactors may be better for the outlying districts where the collection volume is small and there are fewer collection trucks.

R(4) Equipment with an auxiliary loading device to 8 m^3 non-compactors

On the average, the volume of solid waste which can be carried in one trip is as follows:

7.5 m^3	compactor truck	: 2.8 tons
8.0 m^3	non-compactor truck	: 2.2 tons
6.0 m^3	non-compactor truck	: 1.7 tons

A collection crew consists of 5 workers regardless of type of collection trucks. The collection volume per worker for a compactor crew is larger than that of a 6.0 m^3 non-compactor crew because the loading work with compactors is easier. 8.0 m^3 non-compactor trucks have a higher vehicle height and larger tare load than other types of trucks, which makes the loading height higher and the loading work considerably more difficult and time consuming.

To solve this difficulty, addition of an auxiliary loading device (Fig. 3.2) to 8 m^3 non-compactors is recommended. The unit price for this device is about 90,000 Baht. Incidentally, the number of 8 m^3 non-compactors was 248 as of 1981.

S(10) Stock control of spare parts for collection trucks

In many cases, collection trucks which come to the repair shop are forced to wait for a long time for the arrival of necessary parts which are out of stock. This causes a decrease in the operating rate for collection trucks. The spare parts control for collection trucks is comparatively easy because type of trucks and type of equipment to be mounted is limited. The interchangeability of parts for different models can also be checked easily. Furthermore, the classification of high turnover parts (parts in much demand) and low turnover parts(parts in limited demand) will not be difficult if checking of the repair records is done.

Since many parts are imported, the forecast of vehicle breakdown is indispensable information to determine the proper spare stock quantity. For this purpose, detailed and accurate statistic data or breakdown of collection trucks should be obtained and analyzed. In preparation for change of the spare parts control system to the new system based on statistical forecasting in the near future, the completion of basic data such as vehicle history, repair records and maintenance records should be implemented. In order to satisfy the need at present, sufficient provision of high turnover parts should be made urgently. As will be mentioned in S(11), simple repair and maintenance of collection trucks are expected to be performed by the Mechanical Subsection of Sanitation Section in each district, and therefore, the spare parts supply for the repair shop of BOF should be made based on the long-range parts supply program, taking into account the spare supply to Sanitation Section of each district.

S(11) To shorten idle time of collection trucks arising from breakdowns

Currently, the rate of trucks in garages for constant repairs accounts for 18% of the total number of collection trucks, and the average number of days required for the repair is 60 per truck per year. In the case of long distance inter-city trucks, the rate of truck breakdowns is approximately 3% and the number of days in the repair shop is about 10 days per truck per year. Although the operating condition of collection trucks is different from inter-city trucks, it should be possible to reduce the rate of breakdown of collection trucks to 5% and to shorten the total repair time to within 20 days. Without this, a reliable

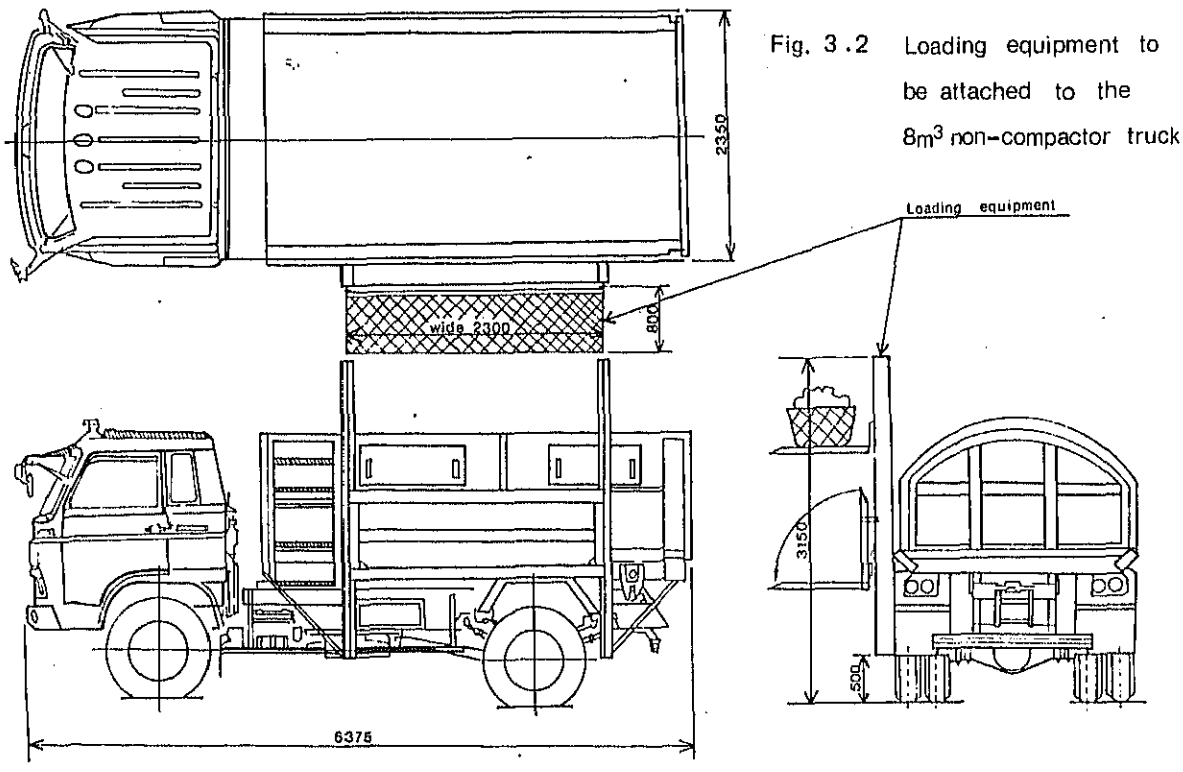


Fig. 3.2 Loading equipment to be attached to the 8m³ non-compactor truck

collection work plan cannot be established. The essential conditions to be realized are:

. To reduce frequency of breakdown of collection trucks

. To shorten repair time

Causes of breakdown of vehicles are broadly classified into the following three categories.

. When a vehicle itself has a structural defect

. When consumable parts reach their life limit

. When defects arise from improper use of the vehicle

There are some cases in which vehicles already have a defect when new, however, occurence of troubles caused by such cases is rare compared with that caused for other reasons; therefore, such cases are not urgent problems to be discussed here. In practice, the check and adjustment of wear of fast wearing parts are performed in daily and periodical inspections, through which replacement of such parts are made as necessary before they reach their service limit. The service life of the parts is normally specified to be shorter than the actual life span from viewpoint of reliability. When trouble occurs as the result of use of a part beyond its service limit or the life span, the effect is not limited to damage of the part in question but also extends widely over other parts. The daily and periodical inspection are the precautional means to prevent occurrence of such problems.

Even if the vehicle has no structural defect, rough driving or improper treatment might cause various defects, which often result in breakdowns or traffic accidents. Improper treatment of vehicles may shorten the life span of even hardly-wearing or wearless parts. To prevent such trouble, drivers and workers are requested to handle collection trucks in a satisfactory manner.

Among the numerous factors to prolong repair time, the main factors to be considered are as follows:

. Owing to lack of skill of mechanics, the work cannot be completed within the standardized work time.

. As work volume exceeds capacity of the repair shop, vehicles have to wasted idle time waiting for their turn.

. Time loss to await the arrival of necessary parts which are out of stock.

. Excessive work volume and lack of skill make the repair incomplete, which causes another breakdown.

In the case of the BOF repair shop, these factors seem to affect each other and make the situation worse than need be.

For reduction of the occurrence of breakdown, the following measures are considered to be effective.

- To oblige drivers to perform daily inspection by themselves and to make collection trucks undergo periodic inspection and maintenance at the repair shop on a routine basis. (Ref. Appendicies 3.4 and 3.5)

- To train drivers and workers on the correct handling of vehicles and make them strictly follow the correct procedures.

- To keep the recording of repair history and log book of collection truck up-to-date for comprehension of the actual conditions of collection and transport, upon which the work plan is established so as to release collection trucks from different conditions.

- To take advantage of every possible opportunity to discover problems or the sign of difficulty at an early stage and make a proper preventive maintenance before the problems increased.

To shorten the repair time, recruitment and training of skilled mechanics is an essential condition; however, this cannot be realized immediately, so, this item is transferred to "R" item (R(5)). Other means to avoid concentration of work at the BOF repair shop are as follows:

- To set up a small repair shop at the Mechanical Subsection of Sanitation Section of each district, where minor repairs and small maintenance can be performed.

- To train drivers to enable them to perform the daily inspection and simple maintenance and repair by themselves. (Ref. Appendix 3.8)

- To perform repair and maintenance in accordance with the maintenance standards and workshop manual specified by individual vehicle manufacturers.

- To adopt the unit replacement system which ensures early return of repaired vehicles to work and utilizes limited skills.

Minor repair and maintenance to be performed at the repair shop of Sanitation Section of each district should be limited to those repairs which can be done with standard common tools without requiring sophisticated skill. Repair work which involves overhaul or requires special tools and equipment, and repair work of safety parts (excluding adjustment) should be conducted at the BOF repair shop.

R(5) Recruitment of skilled mechanics and training of mechanics for repair and maintenance of vehicles

Shortage of skilled mechanics for maintenance and repair of vehicles has become a problem in many countries not only in Thailand. Although state organizations and private enterprises endeavour to train the mechanics, it takes 10 years to educate full-fledged skilled mechanics, whereas the demand for skilled

mechanics is increasing rapidly every year and the shortage of them has become even a more serious problem. As a result, other employers have openly begun to hire qualified skilled mechanics away from other workshops by providing better wage conditions. This tendency has also been seen in Thailand.

The public organizations are unable to offer an arbitrary increase in wages and therefore private enterprises often hire skilled mechanics away from public service.

There is no way other than the modest and long-term approach to solve the problem of shortage of skilled mechanics.

The first action to be taken by the public organizations is to train necessary mechanics themselves; however, if mechanics are simply trained without any protection, it may result in training of mechanics who will leave public service in the future. Therefore, some measures should be taken to prevent the hire of skilled mechanics out of public service.

One of the measures which can be used is to set up an incentive training system in which the training is given on a free-of-charge or with-pay basis, and in return, the mechanics are obliged to work in public service for a fixed period after completion of the training.

In addition, the introduction of an examination system for qualification of the automobile repair and maintenance mechanic, which is now enforced in Japan, is recommended. The system should be so organized as to function well for those who are working for the public organizations and are qualified to undergo the examination or to obtain qualification as a licensed maintenance and repair mechanic.

The second step is to minimize the work which requires skilled mechanics, who are few in number, in order to fully utilize their skills. As a practical means, the process of work can be divided into several stages, so that the work in each stage is simplified. At the same time, the introduction of maintenance and repair equipment to facilitate simplification and automation of the work should be promoted.

Skilled mechanics in the future will be expected to be not only skilled in repair work, but also capable of playing the role of foreman or supervisor who controls the work of his staff.

R(6) Commissioning of private contractors for collection and transport of solid waste

It is recommended that a study be made to commission a private contractor on a contract basis to carry out the solid waste management operation such as collection and transport of solid waste including the intermediate treatment and final disposal of solid waste in some cases. Utilization of a private contractor is effective particularly for the disposal of business waste. Prior to commissioning of private contractors, however, it is necessary to complete the necessary ordinances and regulations in order to carry out the operation effectively.

If BOS undertakes the disposal of business waste and industrial waste including the household solid waste, BOS should provide the equipment and personnel according to the volume of solid waste to be disposed of, which will result in a large organization and rising cost.

If a private contractor carries out this work in place of BOS, they will, of course, provide the necessary equipment and personnel. There is, however, merit in that they will be able to adopt proper scale of equipment and personnel much more freely as compared to a public organization and as a result, they will be able to contract for the work of solid waste disposal at a lower cost than that of a public organization. This has been proven by examples in some cities including Tokyo.

In the case of industrial waste which requires a different method of collection, treatment and disposal, commissioning of a private contractor for the work produces a better result, because a specific contractor can be contracted for the disposal of specific solid waste to be trained as a specialist contractor under administrative guidance.

If BOS tries to fulfill all of these functions, a huge amount of investment and expansion of organization are inevitable.

At present in Thailand, however, there is no contractor who is capable of taking responsibility for treating and disposing of special solid waste such as hazardous waste and contaminated waste. Therefore, some of the work for general solid waste can be transferred to private contractors and capable contractors be guided, trained and assisted when necessary, directing them gradually toward treatment and disposal of industrial waste.

Since it is still impossible to contract with a private contractor for the intermediate treatment of solid waste, based on the present existing conditions, it is recommended that the intermediate treatment of solid waste be centralized at the compost plant of BOS, the contract work be limited to the collection and transport of solid waste, and only when a highly probable final disposal plan is submitted by a contractor, the work be included in the contract upon examination.

An essential condition when the work is to be contracted with a contractor is to draft an effective and highly practical implementation plan in detail and carry out the surveillance and guidance for implementation of the plan.

Since the contract work is carried out with the cooperation of the solid waste management authories and private contractors, a desirable form is such that the contractors undertake their share of the work under the leadership and guidance of the authorities.