(3) Other Disposal Sites

Though Nanjido is the main disposal site in Seoul, other minor sites do exist. A group of small sites scattered in the Sanggye Dong area was used for filling waste from Dobong Gu, but was saturated in August, 1984. The banks of the Han River are used as fill sites for briquet ash separated during the winter season as part of the Han River Development Project.

2-1-5 Recyling System

(1) Recycling Flow

Recycling of materials from solid waste is very active in Seoul. The flow of these materials is shown in Fig. 2-1-8. This shows that recycling is carried out at the source of generation, at the transfer station and at the landfill sites, and moreover, the waste generators themselves sometimes recycle their waste directly to secondary materials dealers and stores.

(2) Self-Support Work Corps

Recycling in the streets, at transfer stations and at the Sanggye Dong disposal site is being carried out by "self-support work corps", which are organized by the police department of Seoul. The corps members are made up of social outcasts such as ex-convicts and beggars who have volunteered to join. Therefore, the police force has established this system of self-support to rehabilitate the members.

The City Police Bureau, Security Division heads 23 district offices to control 64 work corps. Presently, about 1,400 persons are members of the corps. The basic organization is shown in Fig. 2-1-9.

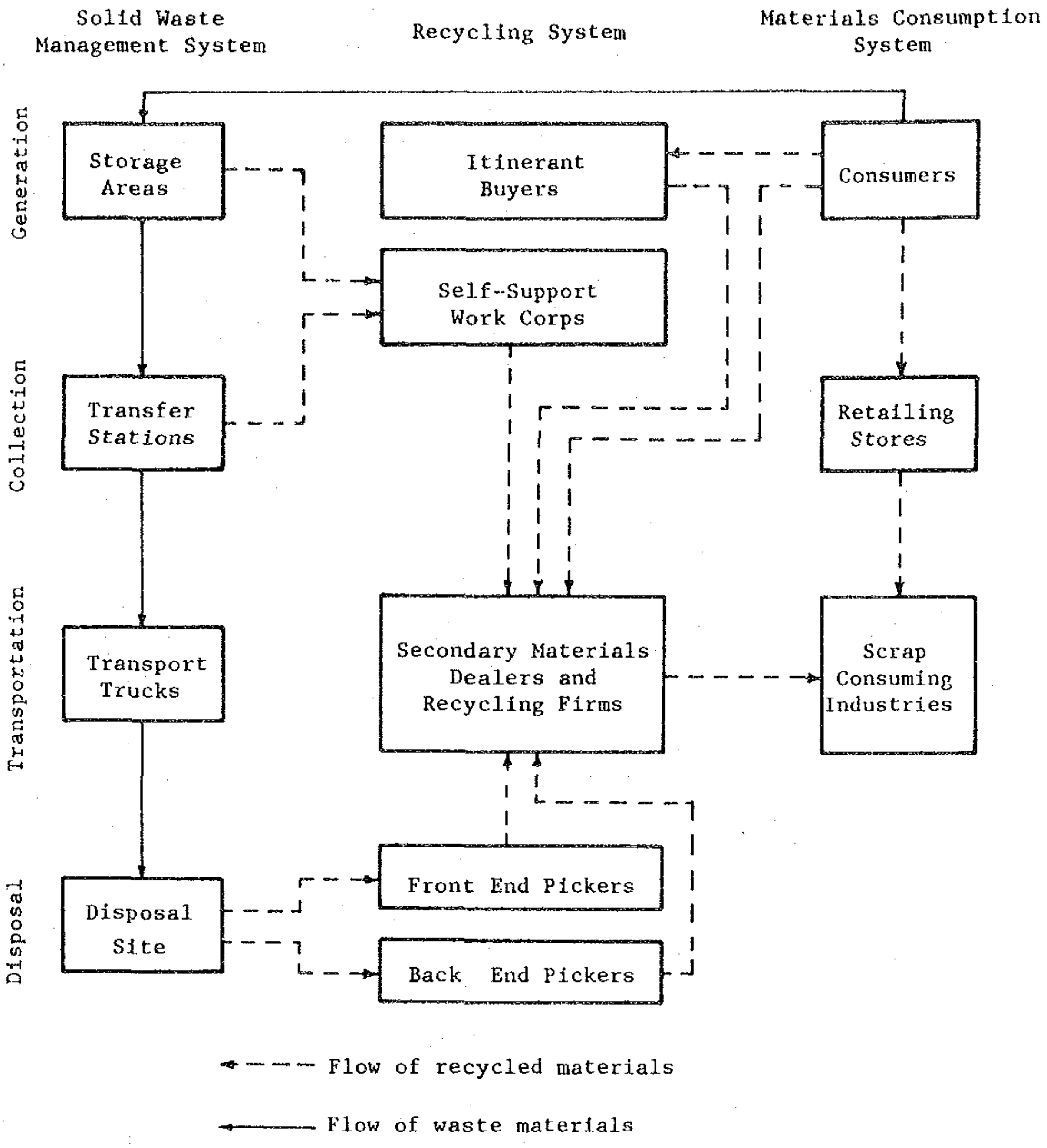


Fig. 2-1-8 Flow Diagram of Waste and Recycled Materials in Seoul

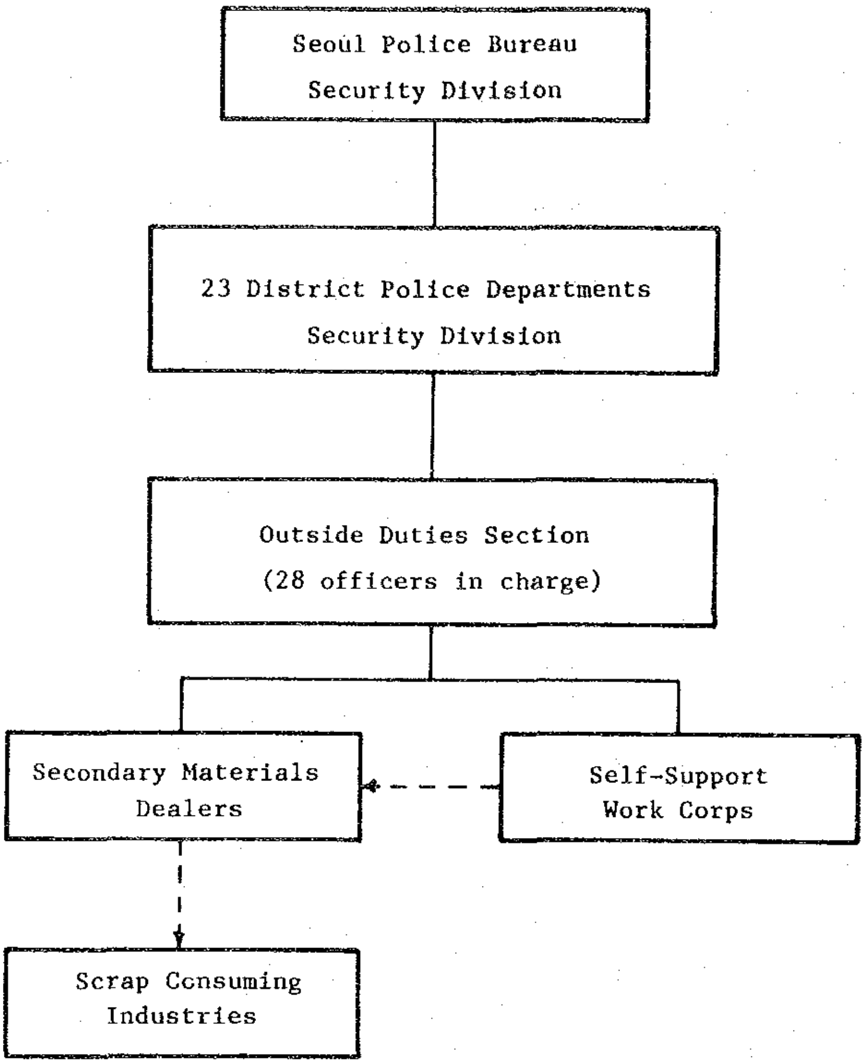


Fig. 2-1-9 Standing of Self-Support Work Corps

The members collect various materials such as paper products, plastic products, textiles, glass and metals. The average recovery rate is 3 t/per/mon. The average income from these materials is ₩150,000/per/mon, with the leader of each corps averaging ₩200,000/per/mon. The transactions are made with secondary materials dealers and not directly with manufacturers.

(3) Recycling at Nanjido

The recycling activities at Nanjido landfill site are managed by the residents of the site. To preserve order, the recyclers are divided into the two functions of front end pickers, or apporis, and back end pickers, or tipporis. The specially qualified apporis are allowed to pick out materials just after the refuse trucks dump waste onto the fill site, whereas the tipporis must be content with working on waste left by the apporis and that which has been spread out by a bulldozer. However, to become an appori, a premium must be paid to work on area and he becomes registered to that specific working area and cannot work at any other area.

These apporis and tipporis are beggars, exconvicts and others who are not socially accepted by the general public, and the working conditions are of the lowest standard. Presently, about 2,500 persons are working at Nanjido as pickers, of which about 43% are apporis. The incomes of apporis are over ₩250,000/per/mon, whereas the tipporis receive from ₩100,000 to ₩300,000/per/mon.

(4) Recovery Rates and Prices of Materials

The annual per person recycling rates for representative materials and, assuming a recycling population of 4,000 persons, the total annual recovery rates are tabulated in Table 2-1-5 , as well as the average unit prices for these materials.

Table 2-1-5 Annual Recovery Rates

Materials	Unit Rate (kg/per/mon)	Total Annual Rate (t/year)	Average Unit Price (W/kg)
Paper	16,164	64,656	60
Plastics	6,432	25,728	100
Textiles	3,588	14,352	20
Glass	11,844	47,376	20
Ferrous Metals	8,160	32,640	40
Nonferrous Metals	1,440	5,760	500
Total		190,512	

2-2 Summary of Basic Field Survey

2-2-1 Waste Generation

Basic field surveys were carried out in summer, autumn and winter in order to know the fluctuation of per capita generation rate and characteristics in each season. Per capita rates for residences were surveyed (Table 2-2-1). Per capita rates are large in individual heated apartments and small in central heated apartments.
The cause of the difference is regarded as the generation of briquet ash.

Among the seasons, per capita rates are small in summer (July) and rather large in autumn (November) and winter (February), which is also considered to be the result of briquet ash generation.

Physical component of waste on dry base was surveyed about 15 samples picked up at independent houses, apartment houses and business facilities. On the other hand, physical component of the waste from Zones I-V was surveyed at Nanjido final disposal site.

Average of physical component from residences and zones are shown in Table 2-2-2 . The result shows that the percentage of briquet ash of zones is higher than that of residences.

Table 2-2-1 Surveyed Per Capita Rate for Residences

Sampling Points		Collected Waste (kg)	Householes	Population	Per Capita Rate (kg/cap/d)
High Level Independent Residence					
Itaeweon Dong	Jul. 27	188/1 Day	23	127	1.480
	Nov. 26	422/2 Days	17	92	2.293
	Feb. 4	299/3 Days	18	76	1.311
Yeoksan Dong	Jul. 28	281/2 Days	57	274	0.512
	Nov. 24	509/2 Days	32	125	2.036
	Feb. 2	415/3 Days	18	67	2.065
Medium Level Independent Residence					
Hwayang Dong	Jul. 25	922/2 Days	147	491	1.010
	Nov. 21	642/2 Days	46	181	1.773
	Jan. 30	692/3 Days	32	109	2.116
Seogyo Dong	Jul. 27	276/1 Day	41	179	1.542
	Nov. 23	235/1.5 Days	18	83	1.888
	Feb. 1	549/2 Days	27	103	2.665
Low Level Independent Residence					
Haendang Dong	Jul. 25	225/1 Day	66	237	0.949
	Nov. 21	403/1 Day	53	236	1.708
	Jan. 30	197/2 Days	25	104	0.947
Bugahyeon Dong	Jul. 27	312/2 Days	67	254	0.619
	Nov. 23	-	-	-	-
	Feb. 1	396/7 Days	12	49	1.155
Average in Independent Residence		-	-	-	(1.533)
	Summer				1.019
	Autumn				1.939
	Winter				1.713
Central Heated Apartment					
Yeoido Dong	Jul. 31	191/2 Days	28	137	0.697
	Nov. 27	119/2 Days	24	106	0.561
	Nov. 27	118/2 Days	24	112	0.527
	Feb. 5	141/1.5 Days	24	101	0.931
	Feb. 5	91/1.5 Days	24	106	0.572
Abgujeong Dong	Jul. 28	255/2 Days	26	134	0.951
	Nov. 24	47/1 Day	12	54	0.870
	Nov. 24	76/1 Day	12	48	1.583
	Feb. 2	119/6 Days	12	53	0.374
	Feb. 2	124/6 Days	12	57	0.363
Average in Central heated Apartment		-	-	-	(0.743)
	Summer				0.784
	Autumn				0.885
	Winter				0.560
Individual Heated Apartment					
Changsin 3 Dong	Jul. 30	493/2 Days	28	141	1.748
	Nov. 26	625/2 Days	29	125	2.500
	Feb. 4	587/3 Days	30	133	1.471
Sinchon Dong	Jul. 28	395/3 Days	16	73	1.639
	Nov. 21	316/3 Days	13	49	2.150
	Jan. 30	246/3 Days	6	25	3.280
Average in Individual Heated Apartment		-	-	-	(2.131)
	Summer				1.694
	Autumn				2.325
	Winter				2.376
Average in Residences					(1.469)
	Summer				1.166
	Autumn				1.716
	Winter				1.549

Table 2-2-2 Average of Physical Component of Waste from Residences and Five Zones in Basic Field Surveys

Unit: % (On dry base)

	Average of Residences				Zone Average			
	Summer	Autumn	Winter	Average	Summer	Autumn	Winter	Average
(Combustibles)								
Paper	19.56	16.33	15.16	17.02	16.17	3.51	5.33	8.34
Wood	6.95	1.97	2.32	3.75	7.44	0.74	0.48	2.89
Textiles	4.81	1.45	0.68	2.31	3.84	1.33	1.23	2.13
Garbage	11.57	13.98	13.67	13.07	10.29	3.56	2.16	5.34
Plastics	8.05	6.02	6.60	6.89	5.98	2.09	1.83	3.30
Leathers and Rubbers	2.48	0.61	0.43	1.17	3.63	0.13	1.15	1.64
Others	1.46	1.05	1.77	1.43	4.54	2.64	1.79	2.99
(Subtotal)	54.88	41.41	40.63	45.64	51.89	14.00	13.97	26.63
(Non-combustibles)								
Ferrous Metals	6.09	2.05	1.95	3.36	3.67	0.26	1.47	1.80
Nonferrous Metals	0.53	0.50	0.61	0.55	0.46	0.08	0.10	0.21
Glass	10.98	4.71	3.36	6.35	10.60	0.68	2.44	4.57
Bones, Stones & Ceramics	6.01	3.96	2.49	4.16	10.30	1.54	0.94	4.26
Others	1.93	0.92	0.85	1.23	2.54	2.31	1.57	2.14
(Subtotal)	25.54	12.14	9.26	15.64	27.57	4.87	6.52	12.98
(Briquet Ash)	19.58	46.45	50.11	38.71	20.54	81.13	79.51	60.39
Total	100	100	100	100	100	100	100	100

2-2-2 Collection and Transportation

Interview surveys were made in July and August in 1984, and time motion surveys by questionnaire were made in July and November in 1984, and February in 1985. These surveys were made to find out the characteristics of solid waste management in 17 Gu's of Seoul. Details of these surveys are described in Appendix.

(1) Results of Interview Surveys

a. Feature of sample people

Nearly a half of the samples were living in the independent houses, and their average family size was 6.2. Their average income ranged from 200,000 to 500,000 won per month.

b. Feature of waste

The amount of daily waste ranged widely from 0.2 to 200 kg, and averaged 10.9 kg, thus indicated 1.76 kg of waste per day per capita was disposed.

c. Storage and collection

Most of people used the dust boxes and plastic buckets for storage. They were collected mostly by Gu early in the morning about 3 times a week. Their average collection fee was 1,360 won per month, and they felt the fee was reasonable or cheap. In addition to the fee, they paid tips of 2,190 won per month in average. Some people disposed their waste inside or outside of their own yard, and some had burned or sold their waste.

d. Waste separation and station disposal

Most of the people agreed to separate the waste into the briquet ash and the others. About 63 percent of people agreed to separate the waste into the briquet ash, combustibles and non-combustibles, however, they do not agree to the separation of waste into each component. As to the station disposal system, only 28 percent of people agreed in this survey.

(2) Results of Time Motion Surveys

a. Schedule

Questionnaires were delivered to the Cleansing Section of each Gu to obtain the needed information:

First survey (Summer) : July 18 to 20, 1984
Second survey (Autumn) : November 19 to 21, 1984
Third survey (Winter) : February 1 to 5, 1985

b. Storage Method

Concrete dust boxes installed on the outside or inside of walls surrounding independent residence occupy about 50% of all storage methods. The collection efficiency to take out waste from these concrete dust boxes is extremely low.

c. Collection Frequency

According to the refuse cleansing law, solid waste should be collected everyday in principle, or at least one time per three days. Actually, collection workers collect solid waste 2 - 3 times per week and everyday for small-scale stores and restaurants (Table 2-2-3). Many workers start for collection at midnight in Summer (Table 2-2-4).

Table 2-2-3 Collection Frequency

Frequency	1st Survey		2nd Survey		3rd Survey	
	Samples	%	Samples	%	Samples	%
Every day	3	5	17	11	4	5
Every other day	37	62	72	48	44	53
Every 2nd day	20	33	63	41	35	42
Total	60	100	152	100	83	100

Table 2-2-4 Starting Time for Collection

Time (o'clock)	1st Survey		2nd Survey		3rd Survey	
	Samples	%	Samples	%	Samples	%
22 - 23	-	-	3	2	-	-
23 - 24			10	7	-	-
24 - 1	4	7	5	3	1	1
1 - 2	12	20	6	4	4	5
2 - 3	28	46	5	3	6	7
3 - 4	12	20	7	4	12	15
4 - 5	2	3	32	21	14	17
5 - 6	1	2	57	37	20	24
6 - 7	1	2	24	16	25	30
7 - 8	-	-	-	-	1	1
12 - 1	-	-	1	1	-	-
15 - 16	-	-	1	1	-	-
17 - 18	-	-	1	1	-	-
Total	60	100	152	100	83	100

d. Collection Workers

Each collection worker has his duty area which was arranged according to physical conditions such as topography, road conditions and situation of areas, age of workers, and traffic conditions. Sometimes, rotation of duty area for collection workers are undertaken for their working conditions. The duty area for one collection worker covers about 200 - 250 households (900 - 1,125 persons). 2,477 road-sweeping personnel clean the streets and side walks covering a length of 1,110 km (width is over 12 m), and also they collect solid waste from small-scale stores and restaurant along the streets. They usually finish their first cleaning work on street before 8 : 30 AM and clean at least 4-times a day on their own duty road with a length of about 450m. That is the reason for the very clean streets and sidewalks in Seoul.

e. Transfer Station

There are 696 small scale transfer stations for unloading solid waste from hand cart onto dump trucks or containers. Manual unloading methods are applied in most cases. Seoul authorities use only 9 loaders for the unloading operation at a few transfer stations.

f. Vehicles

The number and type of vehicles of Seoul City are as follows:

Dump truck	(8.0 - 8.5 t)	297 (58%)
"	(6.0 - 7.0 t)	26 (5%)
"	(2.0 - 4.5 t)	57 (11%)
Container truck	(8.25 t, 16.6 m^3)	34 (7%)
"	(4.0 t, 8.2 m^3)	98 (19%)
Average (7.0 t)	Total	512 (100%)

Dump trucks (8.0 - 8.5 t) and container trucks are mainly used as transportation vehicles. Large number of 8.5 t - dump trucks are arranged for Seongdong-Gu, Dongdaemun-Gu, Seongbug-Gu and Dobong-Gu which are located far from the disposal site at Nanjido.
8.25 t - container trucks are mainly arranged for the Central Business District (CBD) of Jongro-Gu and Jung-Gu and the shopping areas have no open land areas for transfer stations.

g. Number of Trips and Transportation Routes

Number of trips of vehicles between transfer stations and the disposal site (Nanjido) are 2.5 - 6.0. Solid waste had mainly been transported on the Second Ring Road and the roads along the Han River to the disposal site (Nanjido) to avoid traffic congestions.

2-2-3 Recycling

Surveys were carried out on the recycling situation by use of questionnaires and in-person inquiries. Active recyclers, households, commercial establishments and agricultural related organizations were visited for the surveys. As a result, recycling rates, prices of recovered materials, marketability of recoverables and other valuable information were obtained. See Appendix for details.

2-2-4 Final Disposal

(1) Truck Loading Rate

In general, a dump truck cannot load waste to its maximum weight because domestic waste has relatively small bulk density. The amount of waste carried into final disposal site cannot be calculated until the loading rates of the trucks are surveyed. The results of the survey are shown in Table 2-2-5.

The real loading rate of the trucks was calculated as 78% by weighted average, which is referred to in the projection of waste generation rate in subsection 3-3-2.

In this study, a part of transportation trucks were chosen to be weighed. However, almost all trucks should be chosen to know accurate disposal rate. Installation of suitable number of truck scale is recommended to weigh the transportation trucks.

Table 2-2-5 Results of Truck Loading Rate Survey

month	'84 Jul.		'84 Nov.		'85 Jan.		Average*/Total	
Capacity of Truck	Loading Rate(%)	Number of Samples	Loading Rate(%)	Number of Samples	Loading Rate(%)	Number of Samples	Loading Rate(%)	Number of Samples
4.5 ton	75	89	84	72	89	76	82	237
8.0 ton	52	2	80	2	83	3	73	7
8.25 ton	-	0	84	3	80	7	81	10
8.5 ton	60	112	80	153	84	153	76	418
Average*/ Total	64	203	81	230	85	239	78	672

* Weighted average of loading rates and truck number

(2) Final Disposal Rate Survey

Trip numbers of dump trucks to final disposal sites are summarized by each Gu. Disposal rates were estimated with the trip numbers and truck capacities. Three days were decided as the survey date for three seasons (summer, autumn and winter). The results are shown in Table 2-2-6.

(3) Leachate Quality Survey

No countermeasures has been taken at Nanjido final disposal site, thus allows effluent of leachate of high concentration. Leachate samples were ladled at a small pond near the center of Nanjido. The qualities of the leachate is worst in summer and relatively better in winter (Table 2-2-7). The fluctuation of the leachate quality is regarded to be effected by microbial activity varied by temperature.

However, water quality fluctuation of the samples ladled at Nanji River is small because leachate is diluted by fresh water of the river.

Table 2-2-6 Trip Numbers of Dump Trucks and Disposal Rate

Date / Capacity (ton)	Summer			Autumn			Winter*		
	July 25th Wed.	July 27th Fri.	July 30th Mon.	Nov. 21st Wed.	Nov. 23rd Fri.	Nov. 26th Mon.	Jan. 30th Wed.	Jan. 31st Thu.	Feb. 1st Fri.
10.5	0	0	0	10	10	8	28	26	28
8.5	716	682	722	1,172	1,152	1,162	1,378	1,343	1,190
8.25	22	27	29	167	183	186	138	138	104
8.0	245	226	249	433	379	381	440	468	428
7.0	15	14	12	7	7	3	14	7	3
6.5	17	14	20	26	24	21	34	39	34
6.0	35	32	32	63	58	60	16	21	21
4.5	1,187	1,183	1,230	1,756	1,794	1,808	1,559	1,614	1,480
4.0	119	118	127	148	144	164	47	42	45
2.75	14	14	14	0	0	0	0	0	0
2.5	0	0	0	7	7	6	2	9	4
2.0	0	0	0	0	0	0	0	4	0
Road Sweeper	0	0	0	0	0	0	1	2	2
Total	2,370	2,310	2,435	3,789	3,758	3,799	3,657	3,713	3,339
Disposal Rate (In nominal ton)	14,510	14,043	14,856	24,016	23,658	23,868	24,289	24,461	21,909
Truck Loading Rate	0.64			0.81			0.85		
Adjusted Disposal Rate (In ton)	9,290	8,990	9,510	19,450	19,160	19,330	20,650	20,790	18,620

Note: * Excluding Mapo Gu

Table 2-2-7 Quality of Leachate and Stream Water at Nanjido

Sample Number	Season	pH (-)	BOD (mg/ℓ)	COD (mg/ℓ)	SS (mg/ℓ)	T-P (mg/ℓ)	T-N (mg/ℓ)	NH_3-N (mg/ℓ)	NO_2-N (mg/ℓ)	NO_3-N (mg/ℓ)
1	Summer	6.8	27,000	2,700	240	30		1,600	< 0.01	0.34
2		7.7	18	17	40	10		4	1.2	0.95
1	Autumn	8.55	2,900	1,500	220	9	1,200	1,200	< 0.1	6.1
2		7.7	64	28	80	< 5	95	50	< 0.1	0.1
1	Winter	7.80	263	260	150	2	140	170	< 0.1	< 0.1
2		6.90	56	30	40	2	30	40	< 0.1	< 0.1

Note: Sample No. 1 : Leachate from pond near center of Nanjido

Sample No. 2 : Sample from nearby stream

2-3 Problem Identification

The problems observed in the existing solid waste management system of Seoul are identified in Table 2-3-1. The countermeasures to these problems are also proposed in this table.

These problems and countermeasures will be used as bases for forming the Master Plan. Furthermore, the serious problems requiring immediate improvement will be analyzed and considered in the decision of alternatives for the short term project.

Table 2-3-1 Problems of Existing System

Subsystem	Problem		Remedy
	Element	Description	
On-Site Storage	dustchute	unsanitary, inefficient for collection	. plastic bucket with lid, paper and plastic bag
	fixed dust box	inefficient for collection	. same as above
	high moisture content in garbage	unsanitary, inefficient for collection and processing	. dewater garbage, plastic bag
Collection	hand cart	unaesthetic, labor intensive	. compactor collection vehicle, curbside collection
	narrow and/or steep road	inefficient for collection	. road improvement, station collection, city planning
	tip	unequal level of service	. discontinue, labor incentive
Transfer and Transport	long haul distance	inefficient for transport	. mechanized transfer station, processing facility
	manual transfer	unaesthetic, unsanitary, labor intensive	. discontinue and/or direct haul, mechanized transfer station, processing facility
	leachate dripping from vehicle	unaesthetic, oderous, unsanitary	. water tight vehicle
Intermediate Processing	consciousness on processing	inexperienced, misunderstood	. definition (i.e. distinction between disposal and intermediate processing), education of engineer, propaganda
	waste characteristics and quantity	inefficient for processing, marketability of recoverable materials and energy	. separate collection, market development, promotion, institutional arrangement
Resource Recovery	self-support work corps	unsanitary, unaesthetic, unstable income, unsafe	. discontinuation, systematic resource recovery (e.g. intermediate processing, on-site recycling), employment counseling
	scavenging at disposal sites	same as above	. same as above
Final Disposal	dumping at Nanjido	unaesthetic, unsanitary, pollution of environment	. daily soil covering, environmental control (e.g. leachate treatment)
	present landfill site	saturation of Nanjido	. acquisition of new landfill sites, Nanjido mounding, reduction of disposed refuse (e.g. intermediate processing, recycling)
	candidate landfill sites	scarcity	. Nanjido mounding, reduction of disposed refuse(same as above), long distence haul
	incoming truck management	inaccurate information	. truck scale
Financial Aspects	collection fee	insufficient for operation cost, difficulty in securing residents' cooperation	. administrative reform, education, propaganda

CHAPTER 3

FRAMEWORK FOR PLANNING

CHAPTER 3 FRAMEWORK FOR PLANNING

3-1 Projected Populations

In general, population forecasts and population planning are not the same. The indicative population planning established by the government on some plans is decided principally from a standpoint of a population policy referring to the projected population. The result of the projection is not always utilized directly for the population planning. In this study, the estimation of the future population was carried out in consideration of the indicative population by the government and the estimated population from other projects. In particular, it was considered that a more practical figure should be estimated because of the characteristics of this study. The estimate will be used for the projection of the waste generation quantity. Based on the projected waste generation quantity, the scale of the intermediate processing facilities, etc. will be determined.

In this study, some trend analyses using equations such as arithmetic growth formulas, logarithmic growth formulas, logistic curve formulas and exponential growth formulas for annual population increase rate, were carried out. To utilize this method, the increasing trend must be studied carefully. It is necessary that the factors affecting the population increase stably. The data from 1975 to 1983 were used in this study, as during this period, the effects of the population control became apparent. The results of the projections by the trend analyses are shown in Fig. 3-1-1.

The land capacity of Seoul City is estimated here under the following conditions:

- the expansion of the urban area is not taken into consideration;
- the existing land regulations are respected;

- population density in undeveloped areas is estimated to reach 250-400 per/ha after development. The estimation of population density by Gu was carried out considering the population density in the developed areas and also the scale of the development areas in the future. (Generally the population density in large scale developments is lower than that of small scale developments.); and

- in the undeveloped areas, it is assumed that mostly multi-storyed buildings will be built in the future.

The result of the estimation of land capacity was estimated to the about 11.3 - 12.0 million.

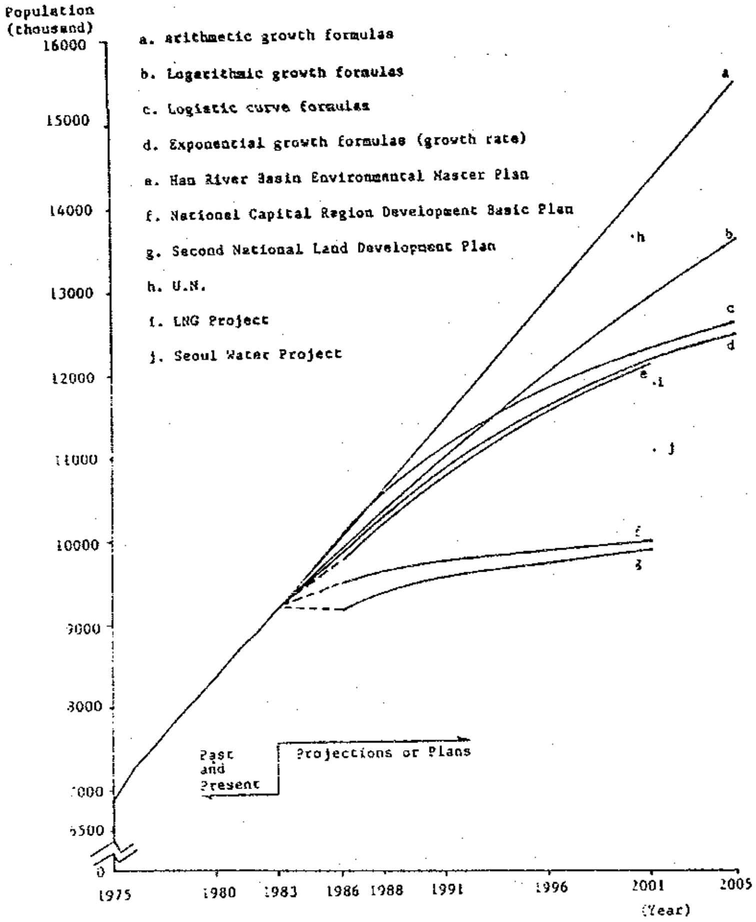


Fig. 3-1-1 Future Populations in Seoul City

As clearly shown in Fig. 3-1-1, the population planned by the government is very small compared with the other figures. The planned population was determined based on the government's population policy to control the population concentration into Seoul City in consideration of the land capacity. Judging from the present population and the increasing trend in recent years, it is quite possible that the future population will go beyond the government's planned population even if any population control policy, as mentioned in the high priority relevant plans, is promoted.

Though the population increase rate has shown a declining tendency since 1976, the absolute annual increase was between 250 thousand and 300 thousand. It is considered that the sudden decline of the population increase is not likely to occur. The natural growth alone was 150 thousand persons in 1981 and 1982, and it shows an increasing tendency. Therefore in this study, the population planned by the government is considered only as an indicative figure.

From the studies on the existing population forecasts, and based on an assumption that the government's population control policy will be promoted continuously, we conclude that the future population in Seoul City will be 12.2 million in 2001 and 12.5 million in 2005 (Table 3-1-1). The estimation is based on the figures projected by the method of exponential growth formulas using the annual increase rate which reflects the declining tendency of population increase due to the population control by the government.

Table 3-1-1 Estimated Future Populations for Study

	1983	1986	1988	1991	1996	2001	2005
Population (thousand persons)	9,204	9,900	10,300	10,900	11,600	12,200	12,500
Annual Growth Rate		(2.46)	(1.02)	(1.91)	(1.25)	(1.01)	(0.61)

Population by Gu and zone are estimated with consideration of the land capacity and other conditions. The results are shown in Table 3-1-2.

The forecast populations go beyond the land capacity estimated under the various conditions. Thus, it will be necessary either to alter the land use regulation of the development restriction area, or to remove the existing facilities from the urban area to the suburbs to substitute them by residential buildings. Nevertheless, as Seoul City will doubtlessly become more overpopulated, a mighty government's policy to control the population concentration is drastically needed.

Table 3-1-2 Estimated Future Populations by Gu and Zone

(Unit: thousand person)

Year Gu	1983	1988	1991	1996	2001	2005
Jongro	277	280	290	290	300	300
Jung	225	230	230	240	240	240
Zone I Total	502	510	520	530	540	540
Seongdong	737	790	810	850	870	880
Dongdaemun	914	960	990	1,020	1,050	1,060
Seongbug	589	610	620	630	640	650
Dobong	813	980	1,070	1,180	1,270	1,320
Zone II Total	3,053	3,340	3,490	3,680	3,830	3,910
Yongsan	335	340	350	350	360	360
Eunpyeong	422	440	450	460	460	470
Seodaemun	423	440	440	450	460	460
Mapo	439	470	490	510	530	540
Zone III Total	1,619	1,690	1,730	1,770	1,810	1,830
Ganseo	635	820	920	1,040	1,140	1,190
Guro	630	660	680	700	720	730
Yeongdeungpo	446	470	470	490	490	500
Dongjag	400	410	420	420	430	430
Gwanak	540	550	560	570	580	580
Zone IV Total	2,651	2,910	3,050	3,220	3,360	3,430
Gangnam	652	900	1,030	1,190	1,320	1,390
Gangdong	727	950	1,080	1,210	1,340	1,400
Zone V Total	1,379	1,850	2,110	2,400	2,660	2,790
Total	9,204	10,300	10,900	11,600	12,200	12,500

Estimated by the study team

3-2 Future Economic Conditions

3-2-1 Fifth Five Year Development Plan

The Korean economy has grown rapidly in the last 30 years. The Gross National Product (GNP) at 1980 constant market prices was W5.0 trillion in 1953 and rose to W45.6 trillion in 1983 at the average annual growth rate of 7 percent. This drastic growth of the Korean economy was attributed to the basic strategy of outlooking industrialization for export promotion, as shown in Table 3-2-1.

The First Five Year Plan started in 1962 under the development policy of positive introduction of foreign capital and export drive. Commodity exports registered an annual growth rate of 38.6 percent in real terms during 1962 to 1966, far above the targeted growth rate of 28.0 percent. Under the Second and Third Five Year Plans, the annual growth rates of commodity exports scored 33.8 percent and 32.7 percent, respectively, surpassing the Government's goal of 17.1 percent and 22.7 percent growths.

The brisk Korean exports, however, were decelerated under the Fourth Five Year Plan (1977-81) partly because of the second oil crisis and partly because of decrease in export competitiveness due to the high inflation and wage hike. In the latter half of the 1970's, the growth rates of GNP and export quantum index were continuously eased. The favorable Korean economic growth since the First Five Year Plan encountered an adverse wind.

The Fifth Five Year Economic and Social Development Plan which started in 1982 gave top priority to "stabilization" to calm down the accelerated inflation since the latter half of the 70's. The first two years were defined as a preparation period to provide stable basis for economic growth, while the latter three years, as the second jump period. GNP was expected to grow, on an average, at 7.6 percent during the planned period.

Table 3-2-1 **Principle Economic Indicators**

Year	GNP				Output of Manufacturing			Gross Investment	National Saving	Imports of Goods	Exports of Goods
		Agri., Forestry and Fishery	Mining and Manufacturing	SOC and Others		Heavy Industry	Light Industry				
at 1975 Constant Market Prices											
1953	2,205	1,078	129	998	325	48	277	301	173	328	36
1954	2,319	1,165	144	1,010	399	62	337	256	142	231	23
1955	2,423	1,182	173	1,068	487	72	415	26	111	312	16
1956	2,390	1,100	197	1,093	584	88	496	194	-42	361	23
1957	2,570	1,204	216	1,150	644	97	547	374	135	371	18
1958	2,711	1,291	236	1,184	705	118	587	316	119	327	16
1959	2,815	1,288	259	1,268	766	132	634	230	87	260	18
1960	2,846	1,261	288	1,297	840	166	674	237	18	290	30
1961	3,005	1,414	301	1,290	856	196	660	296	64	269	38
1962	3,071	1,330	340	1,401	990	267	723	295	75	371	50
1963	3,351	1,456	389	1,506	1,190	349	841	597	286	494	77
1964	3,672	1,684	430	1,558	1,288	419	869	453	282	366	104
1965	3,885	1,688	508	1,709	1,551	539	1,012	473	233	414	147
1966	4,378	1,861	586	1,931	1,809	655	1,154	824	452	661	192
1967	4,669	1,751	704	2,214	2,208	837	1,371	942	489	854	246
1968	5,196	1,774	870	2,552	2,858	1,215	1,643	1,282	748	1,223	346
1969	5,911	1,961	1,037	2,913	3,485	1,526	1,959	1,819	1,189	1,554	494
1970	6,363	1,934	1,240	3,189	4,177	1,844	2,333	1,787	1,156	1,670	634
at 1980 Constant Market Prices											
1970	17,284	4,966	2,823	9,495	9,971	4,415	5,556	4,052	2,519	3,475	1,310
1971	18,797	5,122	3,289	10,386	11,763	5,217	6,546	4,635	2,690	4,206	1,699
1972	19,869	5,272	3,712	10,885	13,544	5,952	7,592	4,164	3,100	4,254	2,472
1973	22,678	5,599	4,776	12,303	17,623	8,195	9,428	5,475	4,857	5,832	3,853
1974	24,425	6,013	5,476	12,936	20,267	9,981	10,286	7,113	4,470	6,814	4,203
1975	26,113	6,308	6,144	13,661	22,709	10,943	11,766	7,235	4,602	6,724	5,006
1976	29,804	6,901	7,493	15,410	28,482	14,277	14,205	8,412	7,831	8,478	6,999
1977	33,590	7,077	8,671	17,842	32,895	17,192	15,703	10,367	10,271	10,149	8,427
1978	36,852	6,430	10,426	19,996	39,681	21,765	17,916	12,734	11,620	13,120	9,614
1979	39,249	6,862	11,394	20,993	44,239	24,898	19,341	15,247	12,019	14,453	9,374
1980	37,205	5,372	11,227	20,606	44,095	24,471	19,624	11,630	8,130	13,164	10,514
1981	39,509	6,688	12,083	20,738	47,210	26,550	20,660	11,890	8,839	13,935	12,343
1982	41,737	6,963	12,514	22,260	49,290	28,070	21,220	12,491	10,359	14,457	12,753
1983	45,635	7,441	13,845	24,349	54,500	31,556	22,944	14,217	12,580	16,468	14,749

Source: National Income Accounts, The Bank of Korea
Economic Statistics Year Book, The Bank of Korea

The Five Year Plan, however, was decided to be wholly revised in July, 1983. The Government of the Republic of Korea judged that the Korean economy had overcomed for these 2 to 3 years various difficult problems arisen both at home and abroad since the end of the 70's. The Korean economy has stepped into a new era by early performance of price stabilization, improvement in balance of payment and a high growth of GNP in 1983. With judgement that the economy had recovered from the recession, the Government wholly revised the original Fifth Five Year Plan and released the Fifth Five Year Economic and Social Development Plan, Revised Plan 1984-1986 on December 22, 1983.

The new Fifth Five Year Plan has been prepared according to a scenario that the developed countries is gradually recovering from the recession since the end of the 70's because of drop in oil prices and eased high interest rate, and comparatively stable economic growth will be lasted. On the other hand, the world trade has been disturbed by delay in re-organization of industrial structure deteriorated due to two time oil crisis. In addition, too much strong U.S. dollar and ever-increasing cumulative external debts in developing countries have discouraged the world financial market. These uneasy factors in the world economy, possibility of another oil price hike and international political disturbance will have much influence on the world economic circumstances in the middle of the 1980's.

Taking into account these factors, the revised Five Year Plan has set the following goals in accordance with the principles of the original Plan, i.e., stability, efficiency and equilibrium:

- to establish an economic structure which enables autonomous development steadily keeping stable economic growth,
- to reduce gap in technology and competitiveness compared with developed countries by promoting high technology industry,
- to improve the amenities of the nation by equalizing the distribution of the nation's benefit and social overhead capital expenditures, and
- to rationalize the government organization so as to cope with change in economic and social conditions.

The major difference between the original and the revised one is summarized in Table 3-2-2, and the principle economic indicators are given in Table 3-2-3.

3-2-2 Korea in the Year 2000

The Korea Development Institute (KDI) drew up a report on "Korea in the Year 2000" after nearly two years of work carried out in cooperation with 11 other state-run research institutes. The report portrays the image of Korea in the year 2000 as an advanced nation. The KDI presents a series of reform-oriented measures, designed to translate the vision into reality.

According to the KDI's projections, Korean GNP and per capita GNP will amount to US$252 billion and US$5,103, respectively, by 2000 both in the 1984 constant prices. The annual average growth rates of GNP will be 7.0 percent from 1984 to 1990 and 7.2 percent from 1991 to 2000, while the world economy will grow at 3.2 percent and 3.3 percent annually during the comparable periods.

The KDI forecast that agriculture, forestry and fisheries will account for 8.3 percent of the GNP by 2000, a sharp drop from 14.2 percent in 1983. The ratio for social infrastructure and service industries is seen to rise to 58.5 percent by 2000 from 56.4 percent in 1983. Table 3-2-4 gives principle economic indicators for Korea in year 2000.

3-2-3 GNP Projections

Future economic conditions in Korea have been projected by the KDI, Korean Research Institute for Human Settlements (KRIHS), other governmental institutes and the study team for the Han River Basin Environmental Master Plan. Forecasts by these organizations and institutes have been reflected in the Fifth Five Year Economic and Social Development Plan, the Second National Land Development Plan, Korea in the Year 2000 and other analytical reports. These data bases will provide some pictures as to future economic conditions in Korea. The comparison of GNP projections is summarized in Table 3-2-5.

Table 3-2-2 Major Differences between Original Plan and Revised Plan

Item	Unit	1983		1986	
		Original	Revised	Original	Revised
Gross National Product	Trillion ₩ at 1980 Value	43.2	45.6	53.7	56.7
	Billion U.S.$ at 1980 Value	70.8	75.1	90.0	93.3
Growth Rate	%	7.5	9.3	7.5	7.5
Per Capita GNP	Thousand ₩ at 1980 value	1,082	1,142	1,283	1,355
	U.S.$ at 1980 value	1,773	1,879	2,170	2,229
Unemployment Rate	%	4.3	4.1	4.0	3.8
GNP Deflator	Growth rate %	11.0	2.9	9.5	2.0
Commodity Exports	Billion U.S.$ at current prices	30.5	23.2	53.0	35.7
Commodity Imports		34.2	24.9	55.5	35.1
Current Balance		-4.9	-1.6	-3.6	0.4
Gross Investment Rate	%	31.1	27.6	32.5	29.5
Domestic Saving Rate		25.7	24.4	29.6	29.3
Foreign Saving Rate		5.4	2.9	2.9	0.2

Source : Fifth Five Year Economic and Social Development Plan (1984-1986), R.O.K., 1983.

Table 3-2-3 Principle Economic Indicators by Fifth Five Year Plan (1984 - 1986)

Item	Unit	1980	1981	1982	1983	1984	1985	1986	1987	1988
Gross National Product	Trillion ₩ at 1980 Value	37.2	39.5	41.7	45.6	49.1	52.7	56.7	60.9	65.5
	Growth Rate (%)	-5.2	6.2	5.6	9.3	7.5	7.5	7.5	7.5	7.5
	Trillion ₩ at Current Prices	37.2	45.8	51.8	58.3	63.3	69.4	76.1	83.4	91.5
	Billion US$ at 1980 Value	61.2	65.0	68.7	75.1	80.7	86.8	93.3	100.3	107.8
Per Capita GNP	US$ at 1980 Value	1,605	1,678	1,746	1,879	1,989	2,105	2,229	2,361	2,502
Balance of Payment										
Commodity Exports	Billion US$ at current prices	17.2	20.7	20.9	23.2	26.5	30.9	35.7	40.4	45.2
Commodity Imports		21.6	24.3	23.5	24.9	27.5	31.0	35.1	39.2	43.8
Current Balance		-5.3	-4.6	-2.6	-1.6	-1.0	-0.3	0.4	1.0	1.2
Investment										
Gross Investment Rate	%	31.3	29.1	27.0	27.6	28.7	29.1	29.5	30.1	31.1
Domestic Saving Rate		21.9	21.7	22.4	24.4	26.7	28.1	29.3	30.4	31.6
Foreign Saving Rate		9.4	7.7	4.5	2.9	2.0	1.0	0.2	-0.4	-0.5

Source : Fifth Five Year Economic and Social Development Plan (1984 - 1986), R.O.K., 1983.

Table 3-2-4 Principle Economic Indicators for Korea in the Year 2000

Item	Unit	1983	1990	2000	Annual Average Growth Rate	
					1984-90	1991-2000
Population	Million persons	39.9	44.1	49.4	1.44	1.14
GNP						
at current prices	Trillion Won	58.4	119.2	342.3	10.7	12.3
at 1980 prices	Trillion Won	45.7	75.8	147.1	7.5	6.8
at 1984 prices	Billion dollar	78.3	125.6	252.1	7.0	7.2
Per Capita GNP						
at current prices	Thousand Won	1,463	2,693	6,837	9.1	9.8
at 1980 prices	Thousand Won	1,145	1,719	2,978	5.9	5.6
at 1984 prices	Dollar	1,962	2,849	5,103	5.5	6.0
GNP Deflator	1980=100	127.8	157.2	232.7	3.0	4.0
Commodity Export	At current price billion dollar	23.2	62.5	230.9	15.2	14.0
Commodity Import	At current price billion dollar	24.9	61.5	224.0	13.8	13.8

Source : Korea in the Year 2000, KDI, 1984.

Table 3-2-5 Comparison of GNP Projections

(Unit: trillion Won at 1980 constant prices)

	1983	1988	1990	2000
Fifth 5-Year Plan	45.6	65.5	-	-
KDI	45.7	-	75.8	147.1
KRIHS	-	-	69.0	132.0
Han River Team	42.2	60.7	70.1	136.0

This report adjusted the above projections by utilizing the newest data available, mainly data from the National Income Accounts published by the Bank of Korea in 1984. The results are presented in Table 3-2-6. The GNP of Korea will grow from W45.7 trillion in 1983 to W185.4 trillion at 1980 constant prices with an annual growth rate of 6.6 percent.

Table 3-2-6 Projection of GNP

(Unit: trillion Won at 1980 constant prices)

Year	GNP	Gross Investment
1983	45.6	14.2
1984	49.5	16.7
1985	53.4	18.2
1986	57.3	19.8
1987	61.3	21.4
1988	65.6	23.1
1989	70.0	24.9
1990	74.7	26.7
1991	79.7	28.7
1992	85.1	30.9
1993	90.9	33.2
1994	96.9	35.6
1995	103.1	38.1
1996	109.7	40.7
1997	116.8	43.5
1998	124.5	46.6
1999	132.1	49.6
2000	140.0	52.8
2001	148.3	56.1
2002	157.2	59.7
2003	166.7	63.4
2004	175.9	67.1
2005	185.4	70.9

3-2-4 Future Seoul Economy

The GRP for Seoul City grew at an average annual increase rate of 11.2 percent in real terms during 1972 to 1981, surpassing the GNP growth rate of 7.9 percent during the comparable period. The percentage of Seoul GRP to GNP which was over 30 percent from 1972 to 1975 dropped to around 28 percent in the latter half of the 70's and again has shown an upturn tendency since 1979, rising above the 30 percent level.

Meanwhile, restraint of over-concentration in the Seoul Metropolitan area is one of the major goals in the Fifth Five-Year Economic and Social Development Plan as well as Korea in the Year 2000 prepared by KDI in November 1984. The regional development proposed by the Plans will ease the over-concentration in Seoul City. Extension of the subway system and construction of new roads will enlarge the commuting area for the Metropolitan area and will contrilate to the dispersion of population. Establishment of industry in regional areas will bring about balanced development in the economy. Taking these into consideration, the projected share of the GNP for Seoul will remain at a 30 percent level of the GNP in Korea for the coming 20 years. The gross investment for Seoul was computed on the assumption that the percentage to the GRP is equal to the ratios of projected level of gross investment in Korea to GNP.

The implicit price deflator of GNP in 1983, when that in 1980 equals 100, comes to 127.7, 2.9 percent higher than that of the previous year. In 1984, the wholesale and consumer prices in Korea continued to be stable despite its robust economic expansion. The GNP deflator in 1984, therefore, will be estimated at 131.5, 3 percent up over a year before. A factor of 1.3135 was applied to convert 1980 prices to 1984 prices. Table 3-2-7 presents the Seoul GRP and gross investment at 1980 and 1984 constant prices.

Table 3-2-7 Projection of Seoul GRP

(Unit : trillion Won)

Year	at 1980 Constant Prices		at 1984 Constant Prices	
	GRP	Gross Investment	GRP	Gross Investment
1983	13.7	4.3	18.0	5.6
1984	14.9	5.0	19.6	6.6
1985	16.0	5.5	21.0	7.2
1986	17.2	5.9	22.6	7.7
1987	18.4	6.4	24.2	8.4
1988	19.7	6.9	25.9	9.1
1989	21.0	7.5	27.6	9.9
1990	22.4	8.0	29.4	10.5
1991	23.9	8.6	31.4	11.3
1992	25.5	9.3	33.5	12.2
1993	27.3	10.0	35.9	13.1
1994	29.1	10.7	38.2	14.1
1995	30.9	11.4	40.6	15.0
1996	32.9	12.2	43.2	16.0
1997	35.0	13.1	46.0	17.2
1998	37.4	14.0	49.1	18.4
1999	39.6	14.9	52.0	19.6
2000	42.0	15.8	55.2	20.8
2001	44.5	16.8	58.5	22.1
2002	47.2	17.9	62.0	23.5
2003	50.0	19.0	65.7	25.0
2004	52.8	20.1	69.4	26.4
2005	55.6	21.3	73.0	28.0

3-3 Waste Characteristics and Generation Rates

3-3-1 Present Status of Waste Generation

(1) Collection Rates and Per Capita Generation Rates

The collected amount of solid waste in Seoul was 2,767,858 nominal tons in 1974 and 8,520,591 nominal tons in 1984 (See table 3-3-1), which implies that the amount increased more than three times in ten years. The per capita nominal generation rate increased from 1.323 kg/cap/day in 1974 to 2.531 kg/cap/day in 1984. The collection rate is corrected by using the truck loading rate and shown in Fig. 3-3-5 together with the forecasted generation rate.

Table 3-3-1 Present Status of Waste Generation in Nominal Ton

Fiscal Year	Population Served[1] (persons)	Quantity Collected[2] (ton/yr)	Per Capita Generation Rate Waste (kg/cap/day)	Per Capita Generation Rate Briquet Ash[3] (kg/cap/day)
1973	5,491,520	2,515,785	1.255	1.170
1974	5,733,937	2,767,858	1.323	1.169
1975	6,164,288	2,905,088	1.291	1.112
1976	6,528,745	3,243,920	1.358	1.131
1977	6,835,309	3,410,472	1.367	1.184
1978	7,477,165	4,203,602	1.540	1.141
1979	7,203,273	5,135,805	1.953	1.041
1980	8,107,503	7,439,579	2.507	1.087
1981	8,359,838	7,676,001	2.516	1.056
1982	8,669,087	7,509,521	2.373	0.941
1983	8,909,710	8,061,617	2.479	0.960[4]
1984	9,197,484	8,520,591	2.531	0.956[5]

1) Population in collection plan

2) In nominal ton

3) Briquet ash in calculated as briquet supply x 0.45

4), 5) Estimated value

Source: Cleansing Division of Seoul City, Fuel Management Division

A special feature of solid waste in Seoul is the large amount of briquet ash. Although the per capita rate of briquet ash is decreasing, the total rate is increasing. This is regarded as the result of increase in the discharge amount of paper and plastics due to the rise in living standards.

The amount of waste was calculated as the product of nominal capacities of refuse trucks and trip numbers. The actual amount is smaller than the figures shown in the table, because the weight of waste hauled by refuse trucks is smaller than the of nominal capacities.

(2) Seasonal Fluctuation

a. Collection Rate

A large quantity of briquet ash is discharged in winter to increase the amount of generated waste. In 1983, the maximum collection amount (845,573 tons) was observed in December and the minimum was 531,788 tons in August. The collected amounts by month are shown in Fig. 3-3-1 (1973 - 1984). The biggest reason for the fluctuation of the waste amount is the generation of briquet ash which is estimated to be about 45% of the weight of fresh briquet. The briquet ash per capita rate was thus calculated from briquet supply data in Seoul. The collected amounts of briquet ash and other waste are discussed later.

b. Seasonal Fluctuation of Briquet Ash and Other Wastes

The largest cause of seasonal fluctuation is considered to be that of briquet ash. The per capita rate fluctuation of briquet ash and other waste in 1983 is shown in Table 3-3-2. Here, total waste was calculated by multiplying nominal ton by 0.8 (Truck loading rate is 0.8, refer to Subsection 3-3-2). Briquet ash amount was calculated as 45% of monthly distribution. The other waste amount was calculated as the difference of total waste and briquet ash.

Briquet ash generation in winter was more than three times of that in summer. However, generation rate of other waste is rather large in summer and the seasonal fluctuation was small.

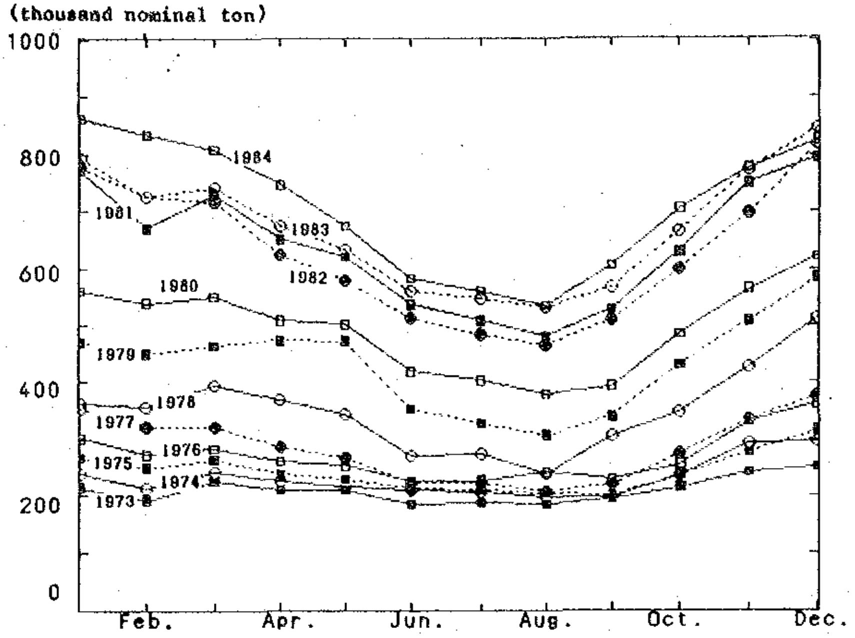


Fig. 3-3-1 Collection Amount of Waste by Month in 1973 - 1984

Table 3-3-2 Seasonal Fluctuation of Waste in 1983

Month	Briquet Ash*		Other Waste**		Total***	
	Per Capita Rate (kg/cap/d)	Ratio	Per Capita Rate (kg/cap/d)	Ratio	Per Capita Rate (kg/cap/d)	Ratio
Jan.	1.468	1.467	0.832	0.847	2.300	1.160
Feb.	1.322	1.321	1.006	1.024	2.328	1.174
Mar.	1.277	1.276	0.876	0.892	2.153	1.086
Apr.	0.970	0.969	1.050	1.069	2.020	1.019
May	0.710	0.709	1.121	1.142	1.831	0.923
Jun.	0.625	0.624	1.052	1.071	1.677	0.846
Jul.	0.469	0.469	1.119	1.140	1.588	0.801
Aug.	0.533	0.532	1.007	1.025	1.540	0.777
Sep.	0.700	0.699	0.995	1.013	1.695	0.855
Oct.	1.124	1.123	0.806	0.821	1.930	0.973
Nov.	1.354	1.353	0.958	0.976	2.312	1.166
Dec.	1.481	1.480	0.968	0.986	2.449	1.235
Average	1.001	1.000	0.982	1.000	1.983	1.000

* Briquet consumption x 0.45
** Total waste - briquet ash
*** Nominal ton x 0.8

c. Waste Collection Rates from Various Generation Sources

The waste generation rates from independent houses, apartment houses, commercial activities and large scale generating facilities are shown in Fig. 3-3-2 and Table 3-3-3. Among these, waste from independent houses and apartment houses are classified into domestic waste, whereas the rest are commercial waste. As shown in the figure, waste generation from the independent houses an the business waste are large in winter. However, waste from the apartment houses and the large amount waste don't fluctuate much. As briquet is used much for heating in the independent houses, the biggest reason for the fluctuation is regarded as the result of briquet consumption.

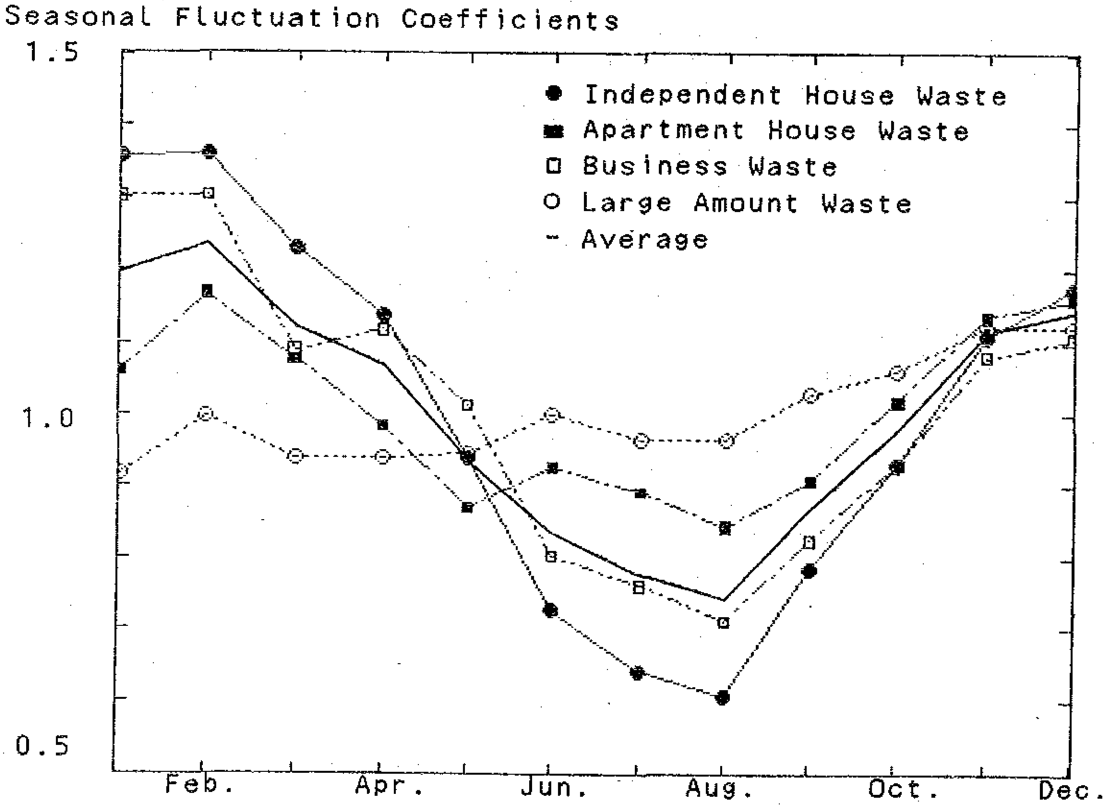


Fig. 3-3-2 Seasonal Fluctuation Coefficients by Generation Sources

Table 3-3-3 Waste Generation Rate from Various Sources in 1984 1)

Month	Independent Houses		Apartment Houses		Business Waste		Large Amount Waste		Total	
	Amount (ton)	Fluctuation Coefficient	Amount (ton)	Fluctuation Coefficient	Amount (ton)	Fluctuation Coefficient	Amount (ton)	Fluctuation Coefficient	Amount (ton)	Fluctuatiom Coefficient
Jan.	478,022	1.356	136,428	1.060	94,461	1.301	154,211	0.918	863,122	1.196
Feb.	448,428	1.360	140,513	1.167	88,400	1.302	156,883	0.998	834,224	1.236
Mar.	432,672	1.228	138,554	1.076	79,166	1.090	157,867	0.940	808,259	1.120
Apr.	387,744	1.137	122,588	0.984	78,513	1.117	158,140	0.941	746,985	1.070
May	330,676	0.938	111,874	0.869	73,560	1.013	158,814	0.945	674,924	0.935
Jun.	247,997	0.727	115,291	0.926	56,391	0.803	162,580	1.000	582,259	0.834
Jul.	233,922	0.640	111,131	0.892	53,428	0.760	162,264	0.966	570,815	0.777
Aug.	213,495	0.606	108,316	0.842	51,590	0.711	162,213	0.966	535,614	0.742
Sep.	267,297	0.784	112,987	0.907	57,877	0.824	167,478	1.030	605,639	0.867
Oct.	327,860	0.930	131,078	1.013	67,557	0.930	178,393	1.062	704,888	0.977
Nov.	378,352	1.109	141,555	1.136	75,944	1.081	183,267	1.121	778,118	1.114
Dec.	414,072	1.175	149,315	1.160	80,322	1.106	182,035	1.120	825,744	1.144
Total	4,160,607	1.000	1,519,630	1.000	857,209	1.000	1,983,145	1.000	8,520,591	1.000

1) Indicated in nominal capacity

2) Annual average = 1.000

d. Seasonal Fluctuation of Moisture Content

Moisture content of each component was measured at Nanjido by Seoul City. The average moisture content of summer and winter of each component is shown below.

(Combustibles)	
Paper	: 34.11%
Wood	: 22.80%
Textiles	: 22.58%
Garbage	: 73.28%
Plastics	: 20.32%
Rubber	: 5.50%
Others	: 15.00%
(Non combustibles)	
Metal	: 0 %
Glass	: 8.06%
Others	: 8.06%
Briquet Ash	: 17.24%

However, this moisture content is considered rather lower than the true value because they are measured after sorting. Moisture must have decreased through sorting. The real moisture content is calculated by multiplying certain coefficient to the value.

Moisture content of each component was calculated for each season by setting up coefficient which is peculiar to each season.

The coefficients are; 1.05 for winter, 1.10 for autumn and 1.20 for summer. The propriety of these coefficients was inspected using the results of basic field surveys. The procedure is shown below.

In the basic field surveys, wet base component percentages were not measured. Only dry base component percentages were measured.

Therefore, moisture content of each component was assumed and tentative moisture content of waste (including all components) was calculated. On the other hand, moisture contents were measured about wastes in the basic field survey. Comparing the tentative moisture contents with measured ones, the best coefficients are decided by trial and error.

The best agreement was presented when the coefficients are 1.05 for winter, 1.10 for autumn and 1.20 for summer (Fig. 3-3-3). Real moisture contents are calculated with these coefficients (Table 3-3-4) and average moisture content measured by Seoul City. Moreover, moisture contents in spring were assumed to be equal to that in autumn.

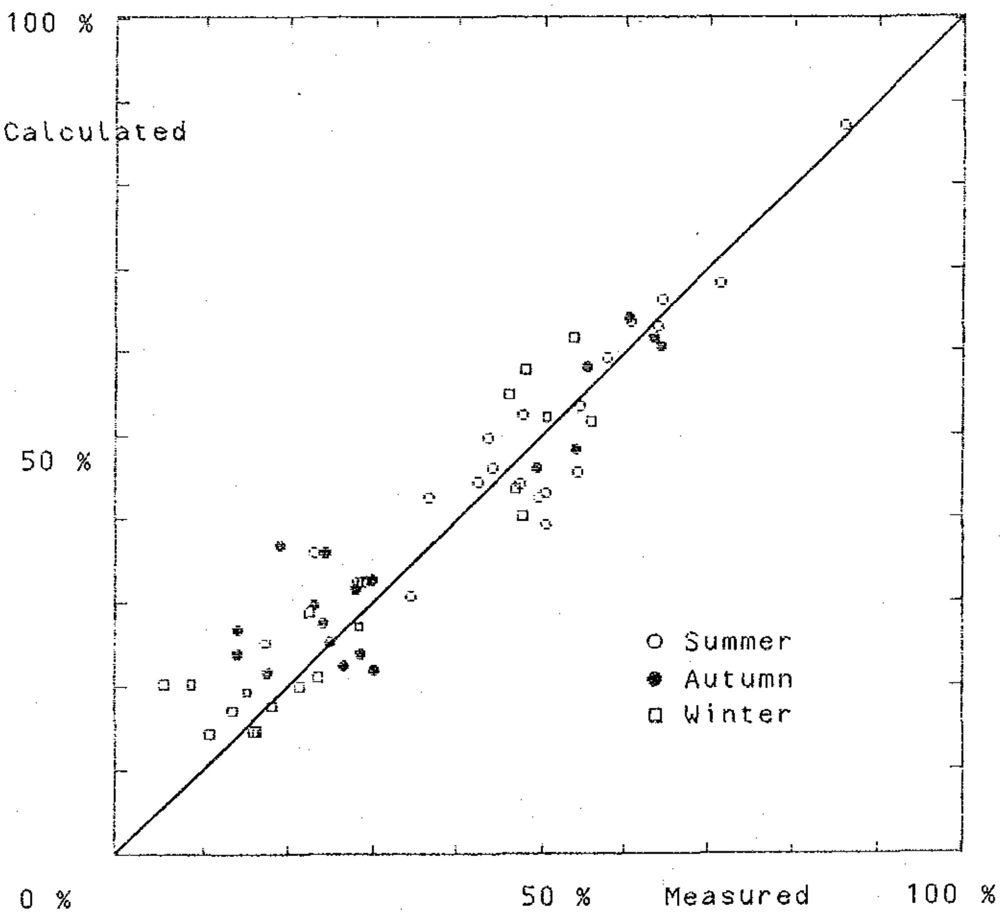


Fig. 3-3-3 Relationship between Measured and Calculated Moisture Contents

Table 3-3-4 Seasonal Fluctuation of Moisture Content

Component	Moisture Content (%)		
	Summer	autumn/Spring	Winter
(Combustibles)			
Paper	40.9	37.5	35.8
Wood	27.4	25.1	23.9
Textiles	27.1	24.9	23.7
Garbage	88.0	80.6	76.9
Plastics	24.3	22.3	21.3
Rubber	6.6	6.1	5.8
Other	18.0	16.5	15.8
(Non combustibles)			
Metal	0	0	0
Glass	9.7	8.9	8.5
Others	9.7	8.9	8.5
Briquet Ash	20.6	18.9	18.1

3-3-2 Waste Generation Forecasts

(1) Forecast Methodology

The forecast of waste characteristics was carried out in accordance with the flow shown in Fig. 3-3-4. The quantity of each component of waste is assumed in proportion to its domestic production. Mainly the national statistics on production data were used, and the national tendency is applied for Seoul City.

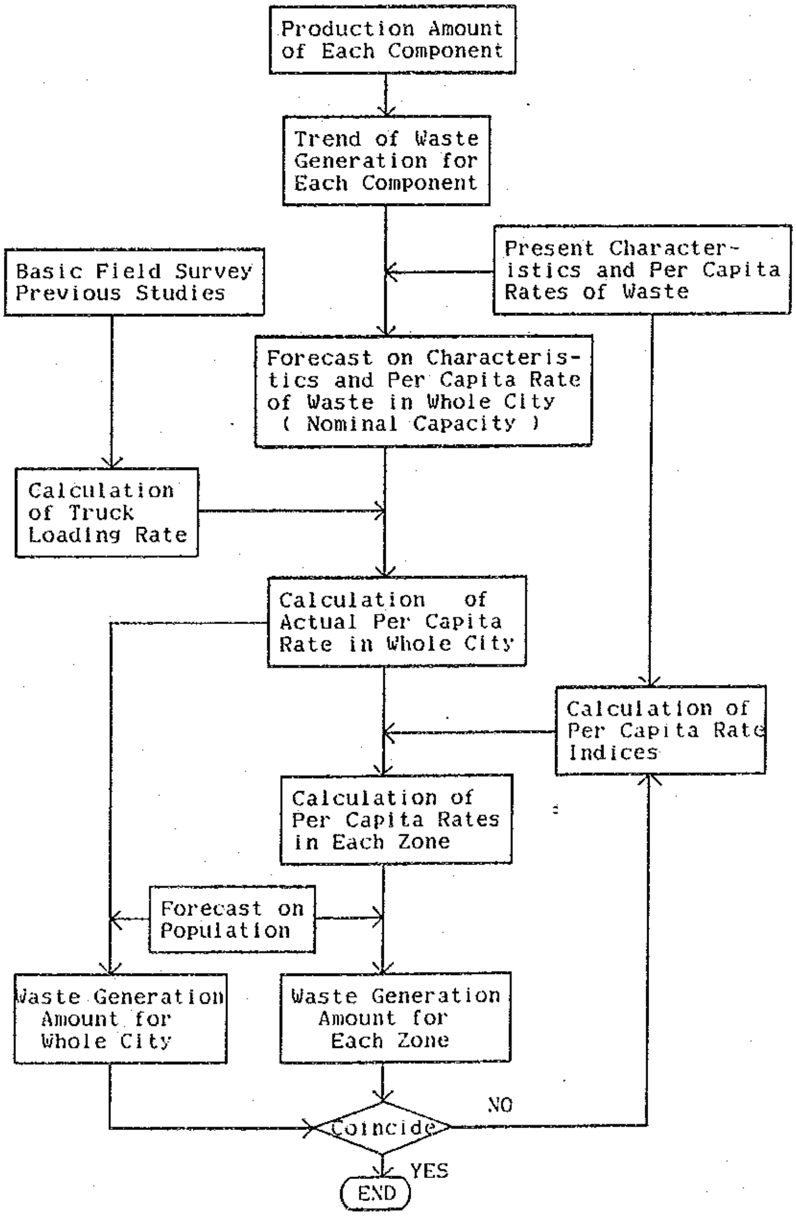


Fig. 3-3-4 Flow of Forecast on Generation Rate of Each Zone

The increasing rates of discharge of individual components (A) were determined from the trends of production of each component. On the other hand, present per capita rates of each component. On the other hand, present per capita rates of each component (B) were calculated from the representative waste composition and the per capita rate of the waste of the whole city. Per capita rate of each component is forecasted from (A) and (B). The future per capita rate of whole waste is calculated as the sum of each per capita rate of the components.

The per capita rates differ highly by zone. To explain this phenomenon, the per capita rate indices of each zone were defined (Equation 1).

$$Z_j = \frac{\text{Per Capita Rate of Zone j}}{\text{Per Capita Rate of Whole City}} \qquad (1)$$

Where: Z_j: Per capita rate index in Zone J (j = 1 to 5)

The present per capita rate indices wre calculated from data of 1983. The waste generation amount is calculated from the per capita rates and population. In this report, the representative waste composition of 1981 is used. The following equations are used for calculation of the waste generation amounts for each zone.

$$Q_{jn} = P_{jn} * Z_j * C_n \qquad (2)$$

$$C_n = R * \sum_i C'_i * (1 + k_i * n) \qquad (3)$$

Here: Q_{jn} : Generation rate in Zone j in 1981+n
P_{jn} : Population in Zone j in 1981+n
C_n : Per capita rate in 1981+n
C'_i : Per capita rate of component i in 1981
k_i : Per capita rate increasing coefficient of component i
n : Number of years from 1981
Z_j : Per capita rate index in Zone j
R : Truck loading rate

As the population increase of each zone is different, the per capita rate indices undergoes a change every year. In order to make the sum of zonal waste generation equal to that in whole city, per capita rate indices are adjusted to satisfy the follwing equation.

$$C_n \cdot \sum_j P_{jn} = C_n \sum_j P_{jn} \cdot Z_j \qquad (4)$$

(2) Forecast on Nominal Capacity in Whole City

Trend of generation rate of each component such as paper or glass in waste is regarded to be in proportion with their production rates. Regression equations of each production is used to forecast waste generation rates in case of paper, textiles and plastics. As for metals and glass, numbers of cans and bottles for drinks were used in the calculation. The amount of garbage was forecasted with food production data. Briquet ash generation was assumed to be 45% of briquet production. The regression equations of the production rate of each component are shown in Table 3-3-5.

On the other hand, the representative waste characteristics of Seoul City in 1981 was calculated from the survey carried out by the Seoul City Cleansing Division. Together with the waste collection data for the whole city, the per capita rates of each component can be calculated (Table 3-3-6).

If it is assumed that the truck loading rate is 100%, the forecasted per capita rates in nominal capacities are listed below. However, the nominal capacity of waste is usually larger than its real weight as it will be clarified later.

In 1988: 2.552 kg/cap/day (incl. 1.217 kg/cap/day of briquet ash)
In 2005: 2.634 kg/cap/day (incl. 0.743 kg/cap/day of briquet ash)

Table 3-3-5 Regression Equations for the Production of Each Component

Component	Regression Equation	Increasing Coefficient(k_i)
	$y = a*t - b$	$k_i=a/(a*1981+b)$
(Combustibles)		
Paper (kg/cap/d)	$y = 0.00838t - 16.51$	0.0824
Wood	-	0
Textiles (kg/cap/d)	$y = 0.00408t - 8.029$	0.0683
Garbage (kg/cap/d)	$y = 0.00427t - 7.083$	0.0031
Plastics (kg/cap/d)	$y = 0.00672t - 13.24$	0.1051
Rubber	-	0
Others	-	0
(Noncombustibles)		
Metals (pcs/cap/d)	$y = 0.00272t - 5.354$	0.0877
Glass (pcs/cap/d)	$y = 0.00364t - 7.167$	0.0832
Briquet Ash (kg/cap/d)	$y = - 0.204t + 41.44$	-0.0197
Others	-	0

Table 3-3-6 Representative Waste Component in Seoul

Component	Percentage [%]	Nominal Per Capita Rate* [kg/cap/d]
(Combustibles)		
Paper	7.20	0.181
Wood	1.77	0.045
Textiles	1.44	0.036
Garbage	17.67	0.445
Plastics	2.93	0.074
Rubber/Leather	0.42	0.011
Others	5.77	0.145
Subtotal	37.20	0.936
(Noncombustibles)		
Metals	0.87	0.022
Glass/Ceramics	2.01	0.051
Briquet Ash	56.11	1.412
Others	3.81	0.096
Subtotal	62.80	1.580

* Total nominal per capita rate was 2.516 kg/cap/d in 1981

(3) Actual Per Capita Rate of Whole City

a. Truck Loading Rate

Since nominal capacity is usually larger than the actual collection amount because loading rates of trucks are less than one, the average of truck loading rates can be calculated with data from the basic field surveys. In the surveys, truck loading rates were calculated by using weight measurements taken at truck scales. The loading rates are given as the quotient of the observed per capita rates and the per capita rate calculated from nominal capacity.

As shown in section 2-2, the average loading rate of the waste transportation trucks was calculated based on the basic field surveys. The loading rate varied from season to season, the weighted average was 78%. In this report, a truck loading rate of 80%, which is on a safe side, is used.

b. Actual Per Capita Rate and Forecast of Generation Rate

From the results of the forecasts on nominal capacities and truck loading rate, the actual per capita rates can be calculated. As shown in Table 3-3-7, the actual per capita rates are 2.042 kg/cap/day and 2.107 kg/cap/day in 1988 and 2005, respectively.

Based on the projected per capita generation rate and the projected population, generation rates are calculated and shown in Table 5-2-1. In Seoul City, about 21,000 ton/day of waste is forecasted to be discharged in 1988, and about 26,000 ton/day in 2005.

The forecasted generation rate, and the observed collection rate adjusted by truck loading rate are shown in Fig. 3-3-5.

(4) Generation Rate from Each Zone

The total waste generation rate for a zone is given as the product of the per capita rate for the whole city, per capita rate index and

Table 3-3-7 Per Capita Generation Rate

In: kg/cap/d

	1981	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
(Combustibles)											
Paper	0.145	0.193	0.205	0.217	0.228	0.241	0.253	0.264	0.276	0.288	0.300
Wood	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036
Textiles	0.029	0.037	0.039	0.041	0.042	0.045	0.047	0.049	0.051	0.053	0.055
Garbage	0.356	0.360	0.362	0.363	0.364	0.365	0.366	0.367	0.368	0.369	0.370
Plastics	0.059	0.084	0.090	0.096	0.102	0.109	0.115	0.121	0.127	0.133	0.139
Rubber	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008
Others	0.116	0.116	0.116	0.116	0.116	0.116	0.116	0.116	0.116	0.116	0.116
(Subtotal)	0.749	0.834	0.856	0.877	0.896	0.920	0.941	0.961	0.982	1.003	1.024
(Non Combustibles)											
Metals	0.018	0.024	0.026	0.027	0.029	0.031	0.032	0.034	0.035	0.037	0.039
Glass/Ceramics	0.041	0.055	0.058	0.061	0.065	0.068	0.072	0.075	0.079	0.082	0.085
Others	0.077	0.077	0.077	0.077	0.077	0.077	0.077	0.077	0.077	0.077	0.077
(Subtotal)	0.136	0.156	0.161	0.165	0.171	0.176	0.181	0.186	0.191	0.196	0.201
(Briquet Ash)	1.128	1.039	1.017	0.995	0.975	0.950	0.928	0.906	0.884	0.861	0.839
Total (Without Briquet Ash)	0.885	0.990	1.017	1.042	1.067	1.096	1.122	1.147	1.173	1.199	1.225
Total	2.013	2.029	2.034	2.037	2.042	2.046	2.050	2.053	2.057	2.060	2.064

Table 3-3-7 Per Capita Generation Rate (cont'd)

In: kg/cap/d

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
(Combustibles)											
Paper	0.312	0.324	0.336	0.348	0.360	0.372	0.384	0.396	0.408	0.420	0.431
Wood	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036
Textiles	0.057	0.059	0.061	0.063	0.065	0.067	0.069	0.071	0.073	0.075	0.076
Garbage	0.371	0.373	0.374	0.375	0.376	0.377	0.378	0.379	0.380	0.381	0.382
Plastics	0.146	0.152	0.158	0.164	0.171	0.177	0.183	0.189	0.195	0.202	0.209
Rubber	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008
Other	0.116	0.116	0.116	0.116	0.116	0.116	0.116	0.116	0.116	0.116	0.116
(Subtotal)	1.046	1.068	1.089	1.110	1.132	1.153	1.174	1.195	1.216	1.238	1.258
(Non combustibles)											
Metals	0.040	0.042	0.043	0.045	0.046	0.048	0.050	0.051	0.053	0.054	0.054
Glass/Ceramics	0.089	0.092	0.096	0.099	0.102	0.106	0.109	0.113	0.116	0.119	0.122
Others	0.077	0.077	0.077	0.077	0.077	0.077	0.077	0.077	0.077	0.077	0.077
(Subtotal)	0.206	0.211	0.216	0.221	0.225	0.231	0.236	0.241	0.246	0.250	0.253
(Briquet Ash)	0.817	0.795	0.772	0.750	0.728	0.706	0.684	0.661	0.639	0.617	0.596
Total (Without Briquet Ash)	1.252	1.279	1.305	1.331	1.357	1.384	1.410	1.436	1.462	1.488	1.511
Total	2.069	2.074	2.077	2.081	2.085	2.090	2.094	2.097	2.101	2.105	2.107

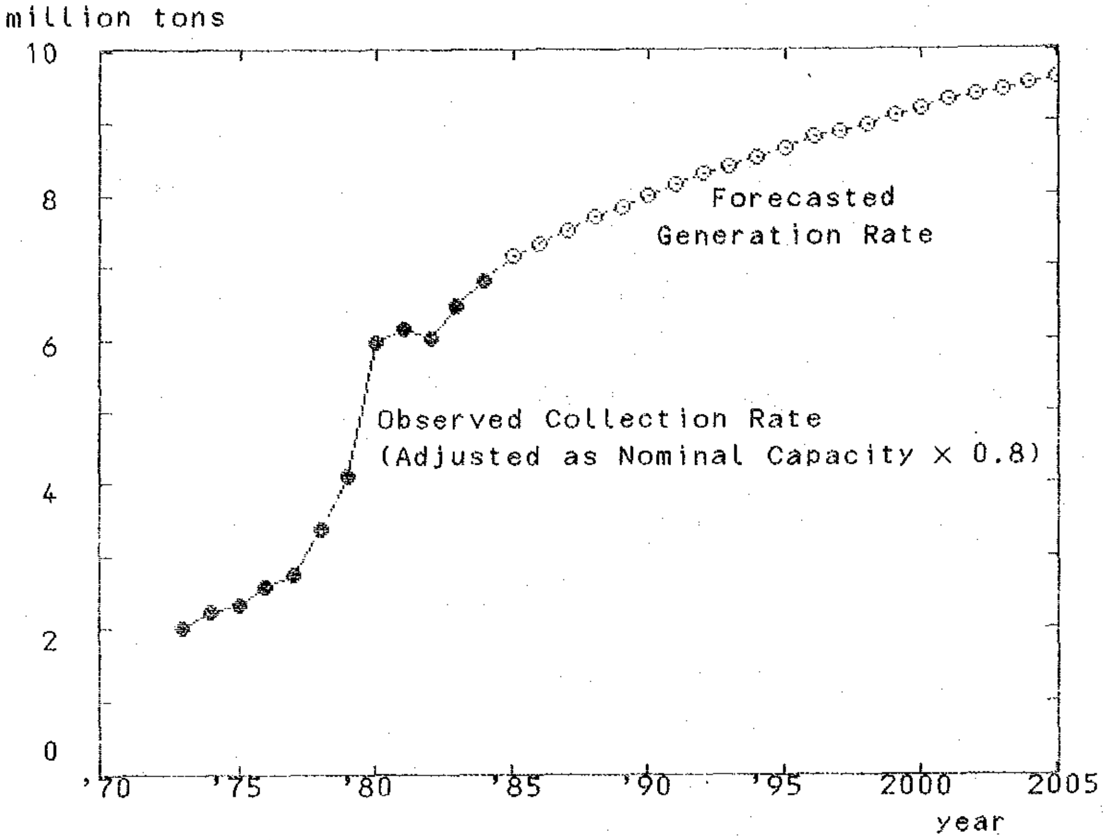


Fig. 3-3-5 Observed Collection Rate and Forecasted Generation Rate

population in the zone. The results are shown in Table 3-3-8. As Zones I and II are already urbanized, further rate of increase of waste will be low. However, in Zone V, high increase will be observed because of its rapid growth in population.

Per capita generation rate is high in Zone I because of its large daytime population and business activity. On the other hand, although the per capita rate of Zone II is the lowest, its waste generation rate is the largest due to its large population.

(5) Dewatered Sludge from Sewage and Nightsoil Treatment Plants

The capacity of Cheonggye/Jungrang sewage treatment plant in 1983 was 360,000 m^3/day, where the amount of dewatered sludge discharge was from 120 to 150 t/day. If it is assumed that the ratio of dewatered sludge to the treatment capacity is constant, the discharge amount of dewatered sludge can be forecasted from it. Therefore, the dewatered sewage sludge generation rates in 1988 and 2005 are 1,120 t/day and 2,090 t/day, respectively.

Table 3-3-8 Waste Generation Forecast by Zone

	Per capita Rate for Whole City (kg/cap/d)	Per Capita Rate* Index	Per capita Rate for Each Zone (kg/cap/d)	Population (persons)	Combustibles (ton/day)	Non Combustible Ash (ton/day)	Sub-Total (ton/day)	Briquet Ash (ton/day)	Total Generation Rate (ton/day)
(In 1988)									
I		2.561	5.229	510,000	1,170	220	1,390	1,280	2,670
II		0.819	1.672	3,340,000	2,450	470	2,920	2,660	5,580
III		1.042	2.128	1,690,000	1,580	300	1,880	1,710	3,590
IV		0.901	1.839	2,910,000	2,350	450	2,800	2,550	5,350
V		1.016	2.075	1,850,000	1,680	320	2,000	1,840	3,840
Total	2.042	1.000	2.042	10,300,000	9,230	1,760	10,990	10,040	21,030
(In 2005)									
I		2.575	5.425	540,000	1,750	350	2,100	830	2,930
II		0.823	1.735	3,910,000	4,050	810	4,860	1,920	6,780
III		1.054	2.221	1,830,000	2,430	490	2,920	1,150	4,070
IV		0.906	1.909	3,430,000	3,910	790	4,700	1,850	6,550
V		1.022	2.153	2,790,000	3,590	720	4,310	1,700	6,010
Total	2.107	1.000	2.107	12,500,000	15,730	3,160	18,890	7,450	26,340

* Per capita rate index for each zone was adjusted to make the sum of generation rate of each zone and the generation rate of whole city.

As for nightsoil treatment plants, a relatively small amount of dewatered sludge (about 6 m^3/day) is discharged. The sludge is well recycled as fertilizer, but the collected amount of raw nightsoil is expected to decrease because septic tank installations are increasing rapidly. Consequently, the amount of dewatered sludge from nightsoil treatment plants will decrease in the future. Thus, dewatered sludge from the nightsoil treatment plants will not have significant effects on the waste management system.

(6) Seasonal Fluctuation Forecast

Seasonal fluctuation is considered to vary in future because generation rate of components such as briquet ash will change.

The fluctuation in 1988 was calculated on following conditions.

1. Fluctuation of sum of combustibles and non-combustibles are calculated as the difference of total waste and briquet ash.

2. Briquet ash fluctuation ratio is assumed to be equal to the ratio in 1983.

3. Fluctuation ratio of total waste is assumed to be equal to the ratio in 1984. Waste amount of each month is calculated as the product of annual average and fluctuation ratio.

4. The ratio of combustibles and non-combustibles is calculated with Table 3-3-7 and assumed to be constant in whole year.

The results are shown in Table 3-3-9 and Fig. 3-3-6.

The fluctuation in 2005 was calculated on following conditions.

1. Fluctuation ratio of combustibles and non-combustibles are assumed to be equal to that in 1988.

2. Briquet ash fluctuation ratio is assumed to be equal to the ratio in 1983.

Table 3-3-9 Seasonal Fluctuation of Waste Characteristics in 1988

Month	Combustibles		Non Combustibles		Briquet Ash		Total	
	Amount (ton/d)	Fluctuation Ratio	Amount (ton/d)	Fluctuation Ratio	Amount (ton/d)	Fluctuation Ratio	Amount (ton/d)	Fluctuation Ratio
Jan.	8,780	0.950	1,660	0.950	14,710	1.465	25,150	1.196
Feb.	10,710	1.159	2,030	1.159	13,250	1.320	25,990	1.236
Mar.	9,040	0.978	1,710	0.978	12,800	1.275	23,550	1.120
Apr.	10,740	1.163	1,040	1.163	9,720	0.968	22,550	1.070
May	10,550	1.142	2,000	1.142	7,110	0.708	19,660	0.935
Jun.	9,480	1.026	1,800	1.026	6,260	0.623	17,540	0.834
Jul.	9,780	1.058	1,850	1.058	4,710	0.469	16,340	0.777
Aug.	8,620	0.934	1,640	0.934	5,340	0.532	15,600	0.742
Sep.	9,420	1.020	1,790	1.020	7,020	0.699	18,230	0.867
Oct.	7,810	0.845	1,480	0.845	11,260	1.122	20,550	0.977
Nov.	8,300	0.898	1,570	0.898	13,560	1.351	23,430	1.114
Dec.	7,750	0.839	1,470	0.839	14,840	1.478	24,060	1.144
Average	9,230	1.000	1,760	1.000	10,040	1.000	21,030	1.000

3. The ratio of combustibles and noncombustibles is calculated with Table 3-3-8 and assumed to be constant in whole year.

The results are shown in Fig. 3-3-7 and Table 3-3-10. In 2005, briquet ash generation rate is lower than that in 1988, which makes seasonal fluctuation smaller.

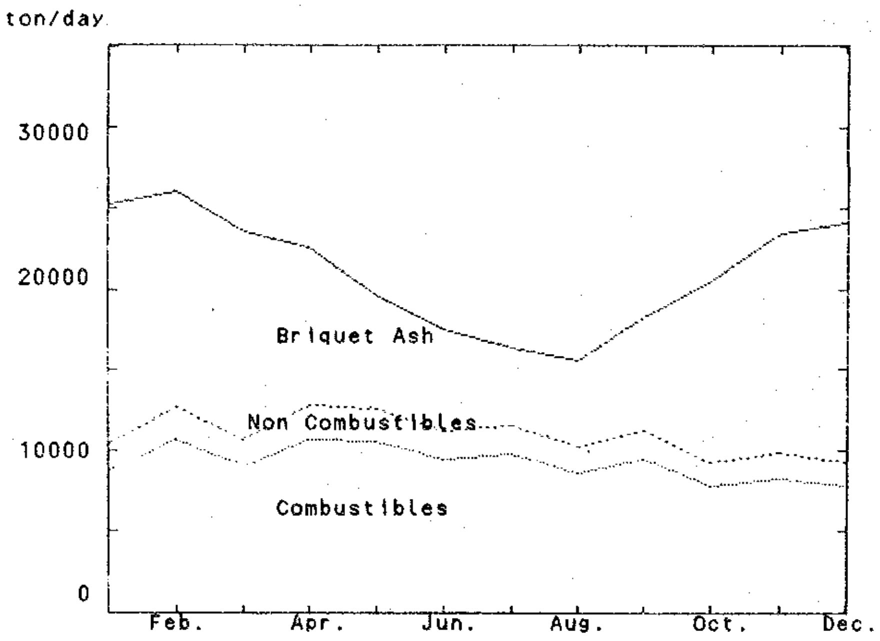


Fig. 3-3-6 Expected Seasonal Fluctuation in 1988

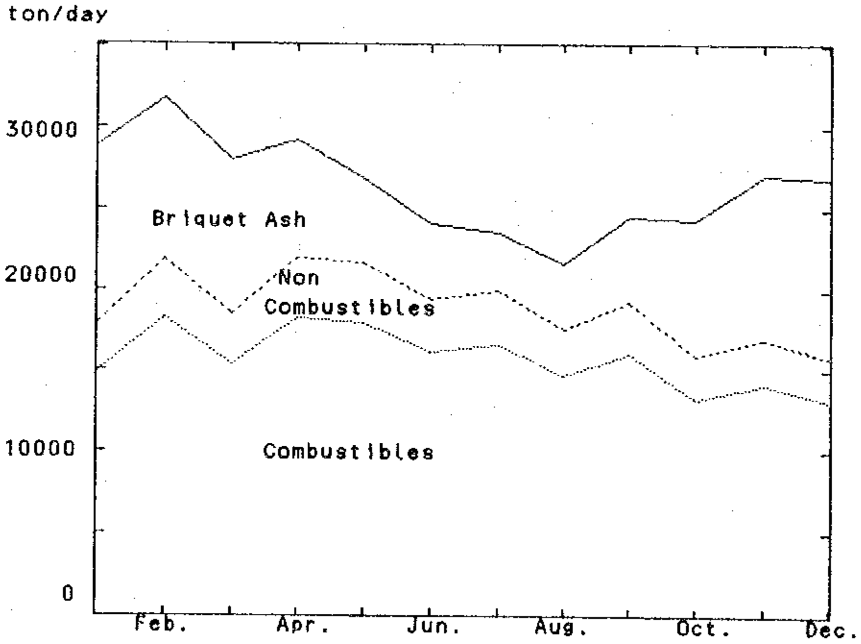


Fig. 3-3-7 Expected Seasonal Fluctuation in 2005

Table 3-3-10 Seasonal Fluctuation of Waste Characteristics in 2005

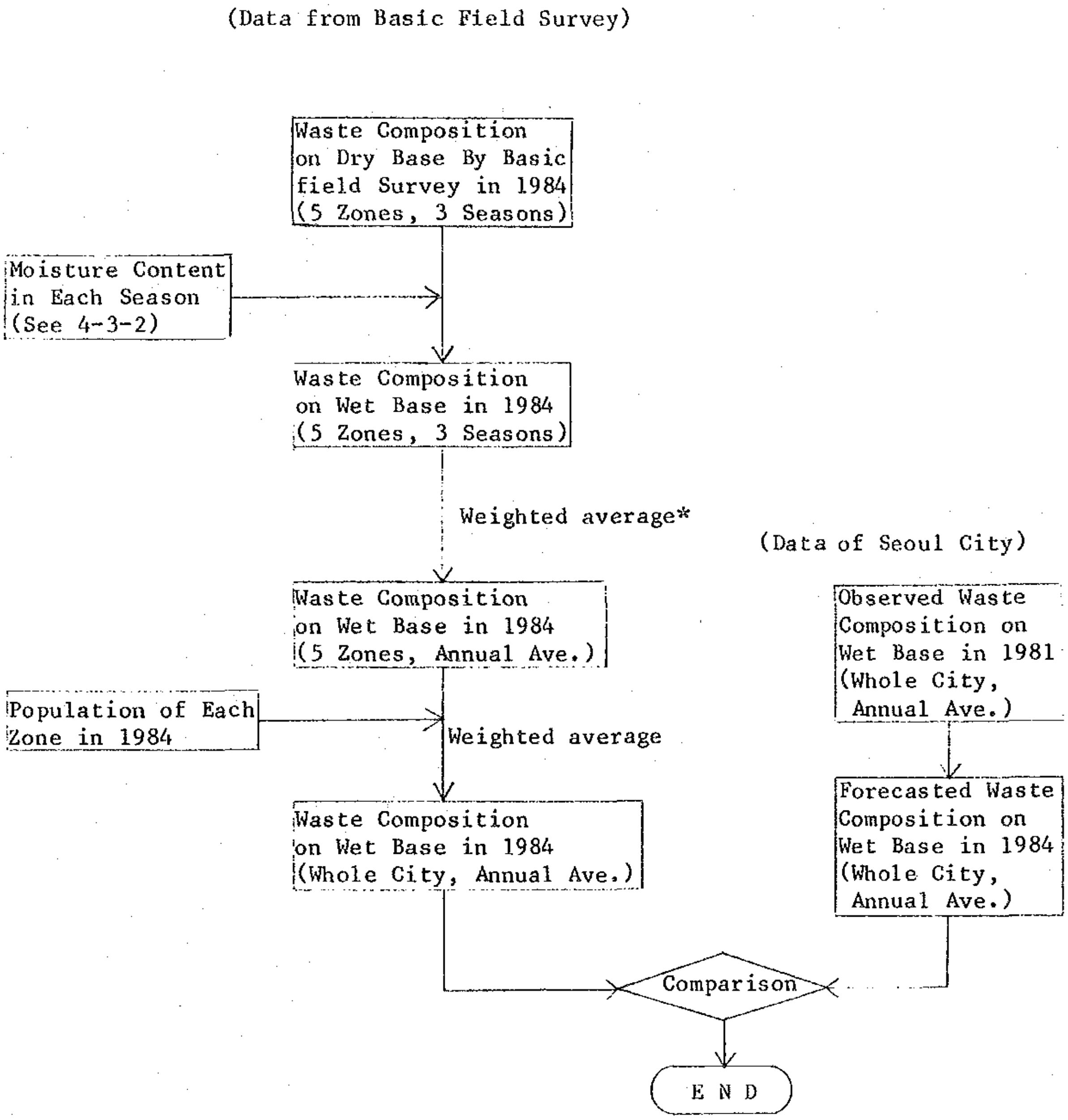
Month	Combustibles		Non Combustibles		Briquet Ash		Total	
	Amount (ton/d)	Fluctuation Ratio	Amount (ton/d)	Fluctuation Ratio	Amount (ton/d)	Fluctuation Ratio	Amount (ton/d)	Fluctuation Ratio
Jan.	14,940	0.950	3,000	0.950	10,920	1.465	28,860	1.096
Feb.	18,230	1.159	3,660	1.159	9,840	1.320	31,730	1.205
Mar.	15,380	0.978	3,090	0.978	9,510	1.275	27,980	1.062
Apr.	18,290	1.163	3,680	1.163	7,220	0.968	29,190	1.108
May	17,960	1.142	3,610	1.142	5,280	0.708	26,850	1.019
Jun.	16,140	1.026	3,240	1.026	4,650	0.623	24,030	0.912
Jul.	16,640	1.058	3,340	1.058	3,490	0.469	23,570	0.891
Aug.	14,690	0.934	2,950	0.934	3,960	0.532	21,600	0.820
Sep.	16,040	1.020	3,220	1.020	5,210	0.699	24,470	0.929
Oct.	13,290	0.845	2,670	0.845	8,360	1.122	24,320	0.923
Nov.	14,130	0.898	2,840	0.898	10,070	1.351	27,040	1.027
Dec.	13,200	0.839	2,650	0.839	11,020	1.478	26,870	1.020
Average	15,730	1.000	3,160	1.000	7,450	1.000	26,340	1.000

(7) Consideration on Representative Waste Component

As shown in Table 3-3-6, the representative waste component in 1981 was given as the base of forecast. Its propriety must be inspected from the data obtained by the basic field survey.

The data in 1981 were obtained at the Nanjido final disposal site by Seoul City Cleansing Division. Among the samples of basic field survey in 1984, samples from five zones taken at Nanjido, were compared with the data in 1981. In the basic field survey, composition of waste components were obtained on dry base, which makes the comparison difficult. Moisture content of every component, which is shown in Table 3-3-4, were used in the calculation of wet base composition. The schematic flow of comparison is shown in Fig. 3-3-8.

The comparison is shown in Table 3-3-11. On the whole, percentages of the components do not differ so much. However, some of the components such as miscellaneous matter and glass show difference. As it is difficult to get the representative waste sample, the difference between the two are considered not to be significant. Consequently, the data in 1981 are used as the representative waste in Seoul City.



* Instead of spring waste, antumn waste was taken into account

Fig. 3-3-8 Flow of Comparison between Waste Composition Surveyed by Seoul City and Results of Basic Field Survey

Table 3-3-11 Comparison of the Component between Basic Field Survey and Seoul City Data

(In wet base)

	Result of Basic Field Sruvey in 1984						Seoul City Date ** (in 1984)
	Zone I	Zone II	Zone III	Zone IV	Zone V	Average*	
(Combustibles)							
Paper	4.41	4.09	7.62	8.04	13.59	7.29	8.94
Wood	2.16	1.71	2.98	0.85	2.15	1.78	1.77
Textiles	1.10	1.02	2.30	1.59	2.58	1.65	1.73
Garbage	22.05	14.39	15.82	22.28	21.16	18.34	17.73
Plastics	2.08	2.79	2.17	2.61	3.01	2.63	3.84
Rubber	0.22	1.41	0.48	0.71	1.55	1.00	0.40
Others	2.76	3.13	2.72	1.67	1.44	2.37	5.73
(Sub-total)	34.78	28.54	34.09	37.75	45.44	35.06	40.14
(Non combustibles)							
Metal	0.49	1.79	0.74	0.38	1.89	1.12	1.11
Glass	3.47	4.67	4.28	4.03	9.02	5.00	2.54
Others	2.11	1.94	1.63	1.14	1.31	1.57	3.80
(Sub-total)	6.07	8.40	6.65	5.55	12.22	7.69	7.45
(Briquet Ash)	59.15	63.06	59.26	56.70	42.34	57.25	52.41
TOTAL	100.00	100.00	100.00	100.00	100.00	100.00	100.00

* Weighted average from components and population in each zone

** Trended data using the data in 1981 (by Seoul City Cleansing Division) as base

3-3-3 Waste Characteristics Forecasts

The per capita generation rates of each physical component were shown in Table 3-3-7. Percentages of the components are shown in Table 3-3-12. The forecast shows a rapid increase of paper and plastics. The content of briquet ash shows a decreasing trend. The percentage of combustible materials will increase from 37.2 % in 1981 to 59.76 % in 2005.

Table 3-3-12 Forecast on Physical Components

(Wet Basis)

Component	(With Briquet ash)			(Without Briquet ash)		
	Observed Data in 1981 %	Forecast for 1988 %	Forecast for 2005 %	Observed Data in 1981 %	Forecast for 1988 %	Forecast for 2005 %
(Combustibles)						
Paper	7.20	11.17	20.46	16.40	21.37	28.53
Wood	1.77	1.76	1.71	4.03	3.37	2.38
Textiles	1.44	2.06	3.61	3.28	3.94	5.03
Garbage	17.67	17.83	18.13	40.26	34.12	25.28
Plastics	2.93	5.00	9.92	6.68	9.61	13.82
Rubber	0.42	0.39	0.38	0.96	0.75	0.53
Others	5.77	5.68	5.50	13.14	10.87	7.68
Subtotal	37.20	43.89	59.71	84.75	84.03	83.25
(Non Combustibles)						
Briquet ash	56.11	47.74	28.29	0	0	0
Metals	0.87	1.42	2.56	1.99	2.72	3.58
Glass/Ceramics	2.01	3.18	5.79	4.58	6.07	8.08
Others	3.81	3.77	3.65	8.68	7.18	5.09
Subtotal	62.80	56.11	40.29	15.25	15.97	16.75

3-3-4 Consideration from Economic Aspects

Generally speaking, there is a relationship between waste generation rates and economical indices such as GNP, income and GRP (Fig. 3-3-9). The reason for this phenomenon is thought to be that, since economic indicators correlate with industrial production, the increase in these indicators means the rise in production of materials such as paper and plastics, which will be discharged as waste.

Moreover, economical improvements influence the way of living. For instance, when the living standard becomes higher, more convenient life styles will be demanded. Then it may cause the increase of one-way bottles and wrapping materials, and a stronger purchasing power can increase the flow of daily necessities.

On the contrary, briquet ash content will go down as the economic status goes up, because briquet will be replaced by other fuels such as oil and gas. This can be witnessed in Fig.3-3-10, for the relationship between per capita generation rate and GRP in Seoul, that when the GRP is low, the generation rate of briquet ash exceeds the total collection rate. This is assumed to be caused by the fact that some amount of briquet ash was self-disposed at the generation sources as well as high generation rate of briquet ash.
According to the regression equation in Fig. 3-3-10, the total waste generation rate is forecasted as 7.775 kg/cap/day in 2005 from the correlation with GRP, which is an absurdly high value.
The regression coefficient is considerably large because of the large increase in waste collection rate during 1978-1980. This drastic increase was probably caused by the change in the waste management system on such matters as the improvement of the collection system.

Consequently, the relationship between GRP and waste generation rate cannot be used in the forecast. However, the generation rate of waste will show a correlation with economic indicators if a drastic change in waste management system does not occur.

On the other hand, the generation rate of briquet ash is forecasted by

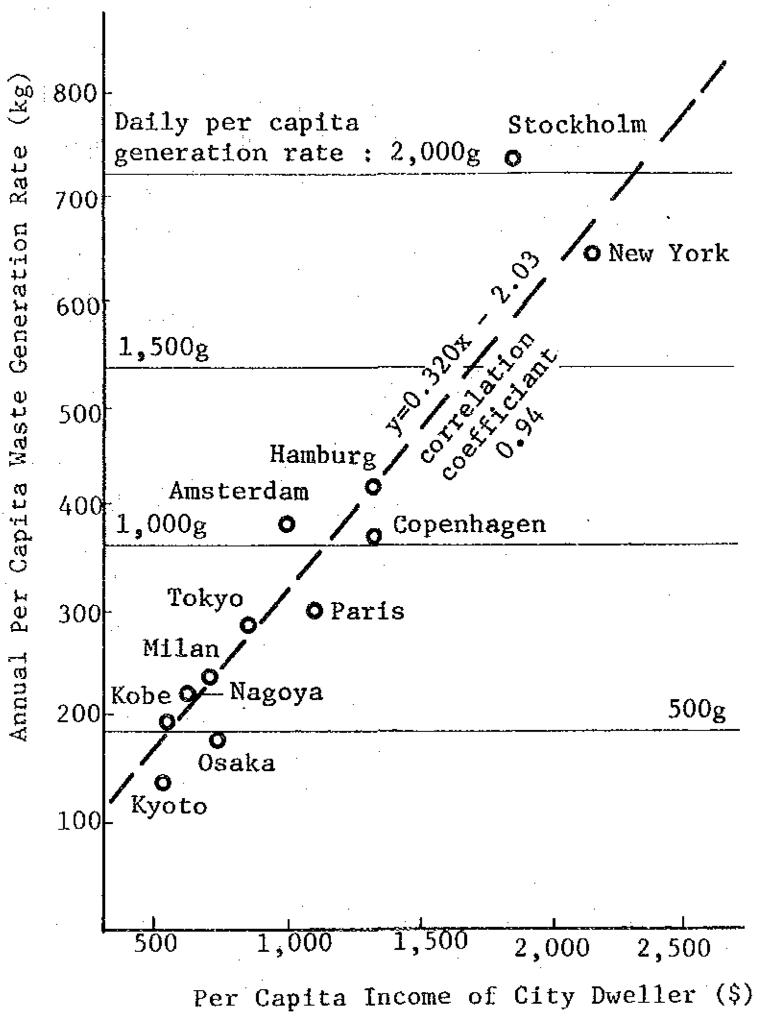


Fig. 3-3-9 Correlation between Waste Generation Rate and Personal Income

Source : Waste Problem,T.Ishibashi, Living Environment Committee,Japan (1971).

another regression equation. The forecasted value is 0.012 kg/cap/day in 2005, which is far lower than the previously forecasted value. The decrease in briquet ash generation rate can be explained by substitution of briquet with oil and gas. However, since briquet is much less expensive than other fuels, the production rate of briquet does not show any decreasing trend. Though briquet consumption is expected to decrease toward 2005, the demand for briquet will probably still exist. Therefore, the generation rate of briquet ash forecasted by production rate, which is on the safe side, is fare estimate(see Fig. 3-3-10).

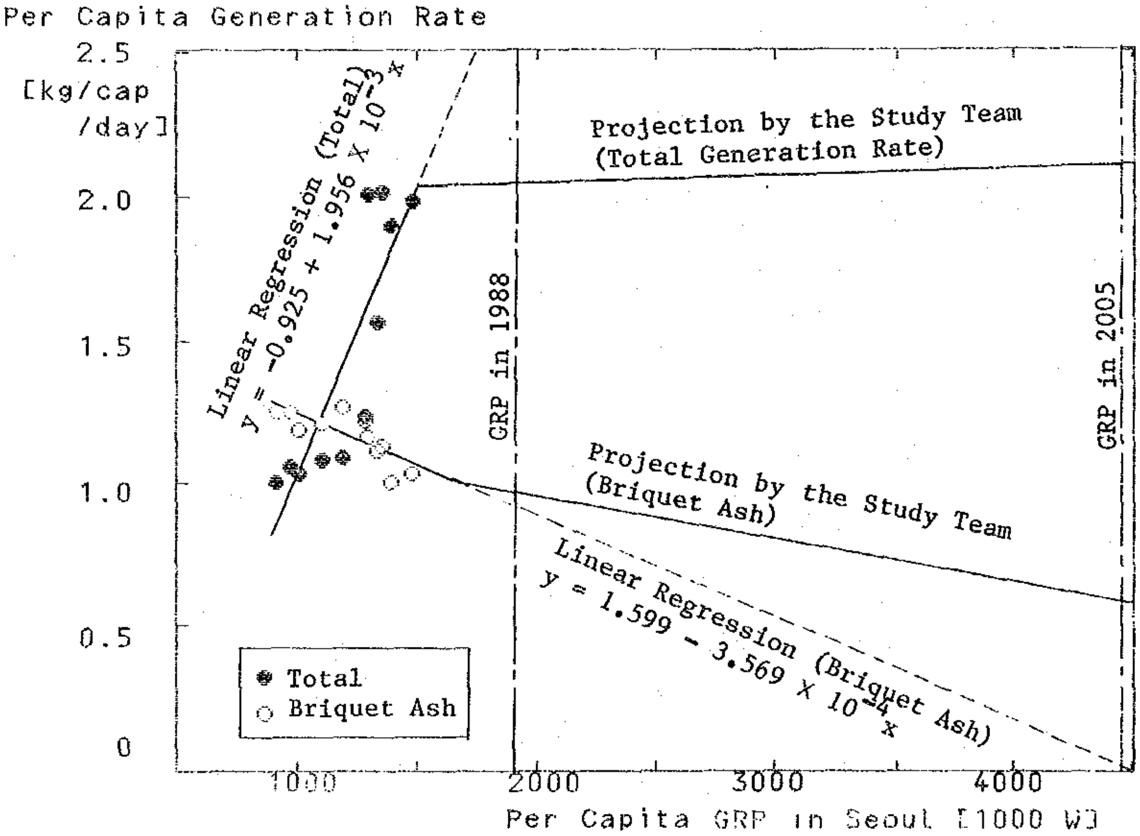
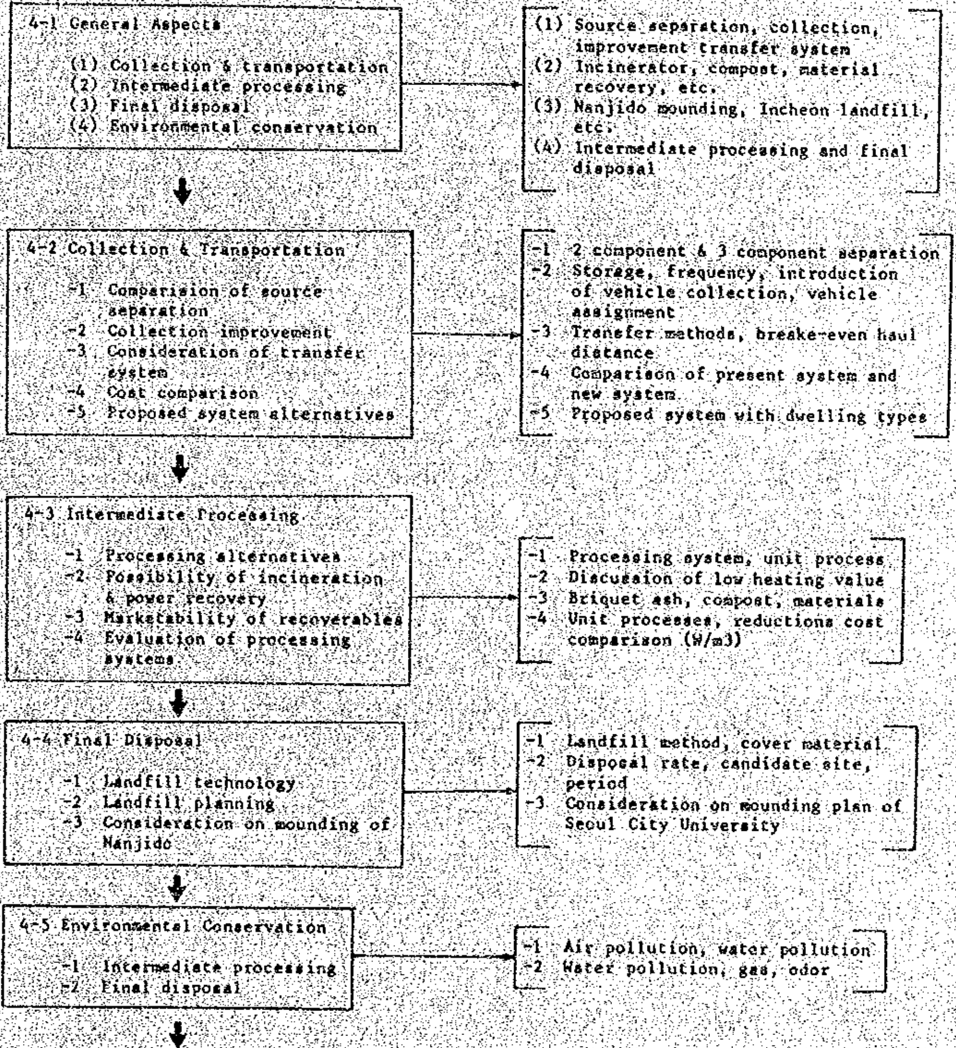


Fig. 3-3-10 Relationship between GRP and Per Capita Generation Rate

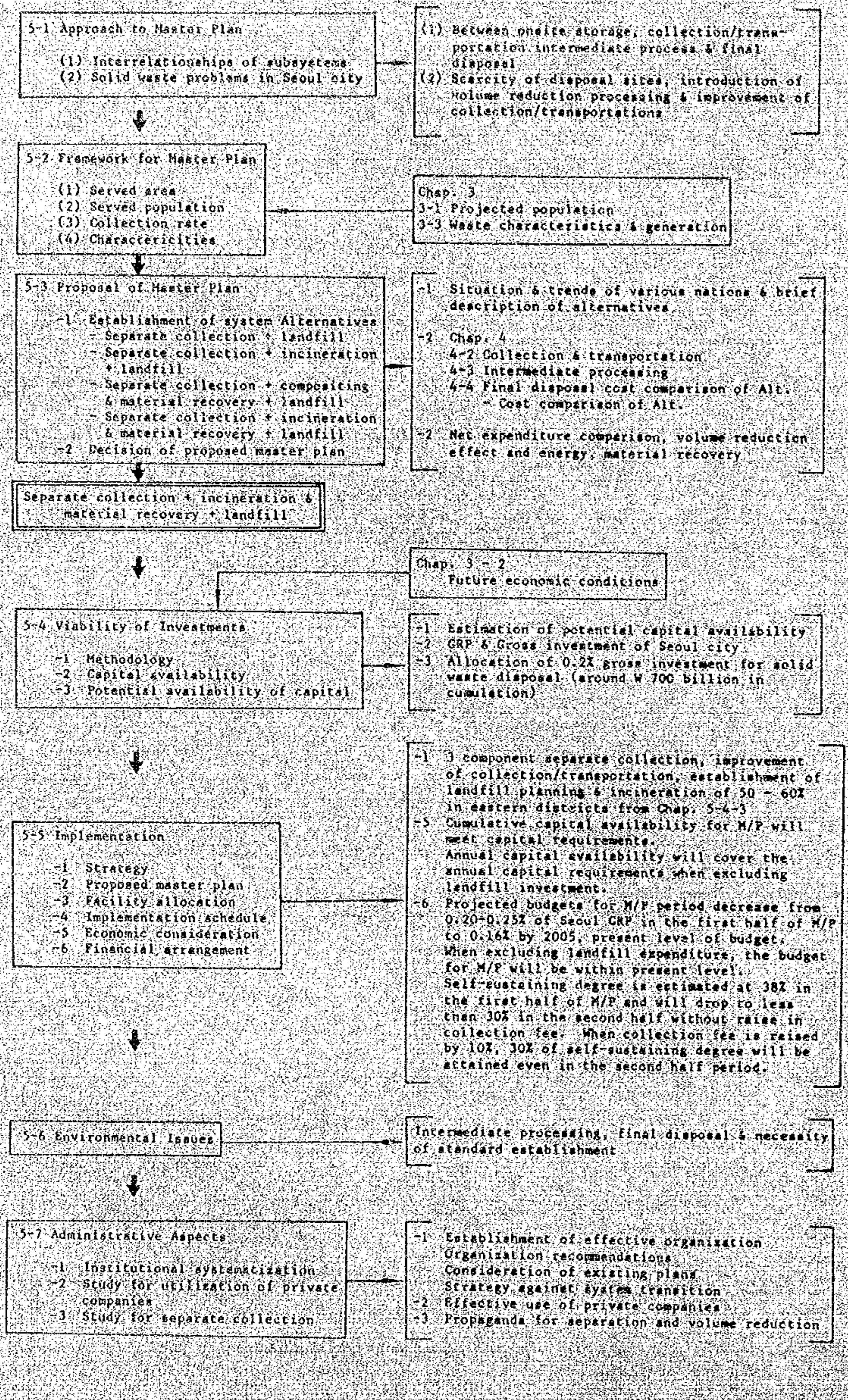
PART II

MASTER PLAN

PART II M/P: (1) Chap. 4 TECHNICAL CONSIDERATIONS



PART II M/P: (2) Chap. 5 PROPOSAL & EVALUATION OF M/P



5-1 Approach to Master Plan

(1) Interrelationships of subsystems
(2) Solid waste problems in Seoul city

(1) Between onsite storage, collection/transportation intermediate process & final disposal
(2) Scarcity of disposal sites, introduction of volume reduction processing & improvement of collection/transportations

5-2 Framework for Master Plan

(1) Served area
(2) Served population
(3) Collection rate
(4) Charactericities

Chap. 3
3-1 Projected population
3-3 Waste characteristics & generation

5-3 Proposal of Master Plan

-1 Establishment of system Alternatives
- Separate collection + landfill
- Separate collection + incineration + landfill
- Separate collection + compositing & material recovery + landfill
- Separate collection + incineration & material recovery + landfill
-2 Decision of proposed master plan

-1 Situation & trends of various nations & brief description of alternatives.

-2 Chap. 4
4-2 Collection & transportation
4-3 Intermediate processing
4-4 Final disposal cost comparison of Alt.
- Cost comparison of Alt.

-2 Net expenditure comparison, volume reduction effect and energy, material recovery

Separate collection + incineration & material recovery + landfill

Chap. 3 - 2
Future economic conditions

5-4 Viability of Investments

-1 Methodology
-2 Capital availability
-3 Potential availability of capital

-1 Estimation of potential capital availability
-2 GRP & Gross investment of Seoul city
-3 Allocation of 0.2% gross investment for solid waste disposal (around W 700 billion in cumulation)

5-5 Implementation

-1 Strategy
-2 Proposed master plan
-3 Facility allocation
-4 Implementation schedule
-5 Economic consideration
-6 Financial arrangement

-1 3 component separate collection, improvement of collection/transportation, establishment of landfill planning & incineration of 50 - 60% in eastern districts from Chap. 5-4-3
-5 Cumulative capital availability for M/P will meet capital requirements.
Annual capital availability will cover the annual capital requirements when excluding landfill investment.
-6 Projected budgets for M/P period decrease from 0.20-0.25% of Seoul GRP in the first half of M/P to 0.16% by 2005, present level of budget.
When excluding landfill expenditure, the budget for M/P will be within present level.
Self-sustaining degree is estimated at 38% in the first half of M/P and will drop to less than 30% in the second half without raise in collection fee. When collection fee is raised by 10%, 30% of self-sustaining degree will be attained even in the second half period.

5-6 Environmental Issues

Intermediate processing, final disposal & necessity of standard establishment

5-7 Administrative Aspects

-1 Institutional systematization
-2 Study for utilization of private companies
-3 Study for separate collection

-1 Establishment of effective organization
Organization recommendations
Consideration of existing plans
Strategy against system transition
-2 Effective use of private companies
-3 Propaganda for separation and volume reduction

CHAPTER 4

TECHNICAL CONSIDERATIONS

CHAPTER 4 TECHNICAL CONSIDERATIONS

4-1 General Aspects

Master plan alternatives are established in two ways. One is by waste stream, that is, combination of source separtion and intermediate processing. The other one is by processing rate in the target year. The former will be assessed for technical feasibilities and the latter will be evaluated for economic and financial feasibility.

The following sections examine the technical aspects of each subsystem described below in detail.

Collection/Transportation	:	Along with onsite storage,the following topics will be studied. 1. Source separation introduction 2. Collection improvement 3. Transfer system introduction
Intermediate Processing	:	Processing alternatives such as incineration and material recovery are studied. Each alternative is evaluated from technical and economic viewpoints.
Final Disposal	:	Consideration on the Nanjido mounding plan by Seoul City University, and schedule requirements for Incheon coastal landfilling will be investigated and acquisition of subsidiary landfill sites will also be considered.
Environmental Conservation	:	Environmental effects accompanied by construction of landfill site and incineration plant will be studied, and recommendations will be made on final disposal and intermediate processing

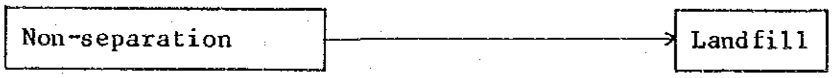
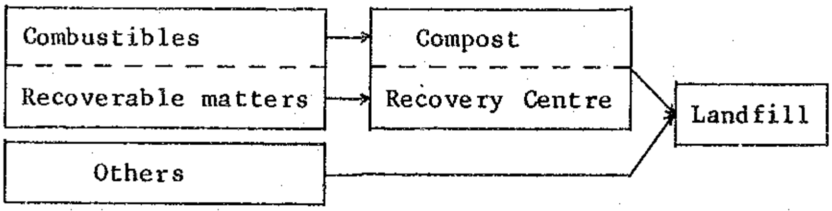
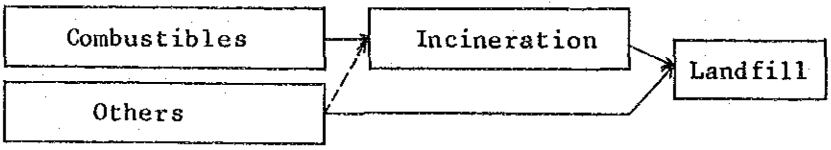
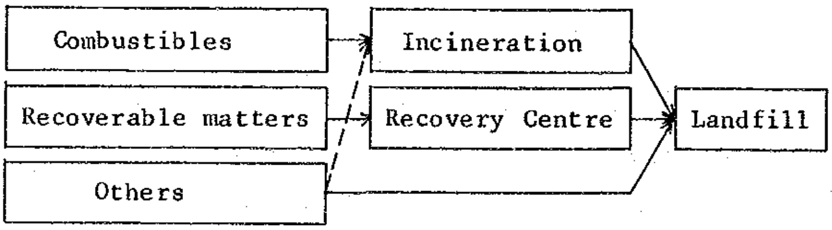
4-2 Collection and Transportation

4-2-1 Comparison of Source Separation

The necessity of source separation depends on the type and purpose of solid waste management system, such as landfilling type, material recovery, incineration, and composting. This study aims to identify the adoptability of intermediate processing facility for volume reduction of waste, and the possibility of material recovery as described in Section 5-1.

Representative separation methods as related to the purpose of the system are shown in Table 4-2-1.

Table 4-2-1 Example of Separation Methods

Purpose of System	SYSTEM	Separation Component
Landfill only		1
Material Recovery		2 (or More)
Volume Reduction		2 ——— (1 – – –)
Volume Reduction + Material Recovery		3 (or More)

Waste should be collected separately for effective intermediate processing. On the other hand, it is desirable for citizens to discharge waste freely without regulation.

Considering these factors, the following separation alternatives are studied for Seoul.

- Alternative I (3 component separation; for incineration and material recovery)
  Combustibles, Non-combustibles, Briquet ash

- Alternative II (2 component separation; for incineration and citizens' cooperation)
  Combustibles + Non-combustibles, Briquet ash

- Alternative III (2 component separation; for incineration)
  Combustibles, Non-combustibles + Briquet ash.

These alternatives will be evaluated taking into consideration: (1) existing discharge situation and applicability of citizens' cooperation, (2) fitness of intermediate processing, and (3) cost comparison of the separation alternatives.

(1) Existing Discharge Situation and Applicability of Citizens' Cooperation

In Seoul, waste is assorted into 3 components from its characteristic, generation rate, and storage methods; combustibles, non-combustibles and briquet ash. The composition rate of combustibles and briquet ash is fairly large compared with non-combustibles as shown in Table 4-2-2.

Table 4-2-2 Generation Rate and Forecast

Component	Observed Data in 1981	Forecast for 1988	Forecast for 2005
Combustibles	6,500 t/d 37.20 %	9,230 t/d 43.88 %	15,730 t/d 59.71 %
Briquet Ash	9,800 t/d 56.11 %	10,040 t/d 47.75 %	7,450 t/d 28.29 %
Non-Combustibles	1,170 t/d 6.69 %	1,760 t/d 3.37 %	3,160 t/d 12.00 %
Total	17,470 t/d 100.0 %	21,030 t/d 100.0 %	26,340 t/d 100.0 %

Generation rate of both combustibles and non-combustibles tends to increase while briquet ash tends to decrease with time, however the ratio of briquet ash is estimated to grow to nearly 30% of waste in 2005.

The present storage method of each component is shown in Table 4-2-3 in accordance with dwelling type.

Applicability of source separation depends on the present discharge situation as follows:

- Independent house

  Waste has been already discharged separately into 2 components; briquet ash and others, so reformation is not needed to perform Alt. II. The applicability of Alt. I (3 component separation) and Alt. III (combustibles, others) are regarded at the same level when judged from requirement for dividing combustibles from the others.

- Apartment house with dust chute

  Performing the source separation in this dwelling type is difficult as the present system (waste is discharged through dust chute as occupants desire without regulation) is desirable for the residents. But the present system has problems such as odor, leachate and putrescence as garbage is stored in the pit. To improve these unsanitary conditions, garbage should not be stored in the dust chute pit regardless of whether source separation is necessary.

  To this point, applicability of 3 alternatives of source separation is more or less the same as waste is brought to the appointed place by hand.

- Apartment house without dust chute

  Waste is discharged at the designated place (storage shed or fixed dust box) beside the apartment house. Thus, it will be easy to adopt the source separation system by using the designated containers for each waste.

Applicability of the separation alternatives according to the dwelling type is evaluated in Table 4-2-3.

There is not much difference among 3 alternatives except the convenience of Alt. II for independant houses, and a slight difficulty with Alt. I for apartment houses with dust chutes.

Table 4-2-3 Present Storage Method and Applicability of Separation Alternatives

○: Easy △: Possible ✕: Difficult

Type of Dwelling	Present Storage Method	Applicability of Sparation Alternative on citizens' cooperation		
		Alt. I (3 comp)	Alt. II (2 comp)	Alt. III (2 comp)
Independent House	Combustible → Concrete Dust Box Plastic container Wooden Box, Metal Can, Drum Can Non-Combustible → Concrete Dust Box Plastic container Wooden Box, Metal Can, Drum Can Briquet Ash → Open storage by the house	△	○	△
Apartment House with Dust Chute	Combustible → Dust Chute and pit Non-Combustible → Dust Chute and pit *Briquet Ash → Dust Chute and pit	✕	△	△
Apartment House without Dust Chute	Combustible → Storage Shed Non-Combustible → Storage Shed Briquet Ash → Storage Shed	△	△	△

* Briquet ash is not generated in the central heated apartment house

(2) Fitness of Intermidiate Processing

The main purpose of intermediate processing, judged from the existing situation in Seoul, is the volume reduction of waste and material recovery.

When incineration is adopted for volume reduction effect, combustibles are required to be separated from the others to obtain the heating value to secure self-burning combustibility, and for electric energy recovery as described in section 4-3-2.

For material recovery, non-combustibles are recommended to be collected separately.

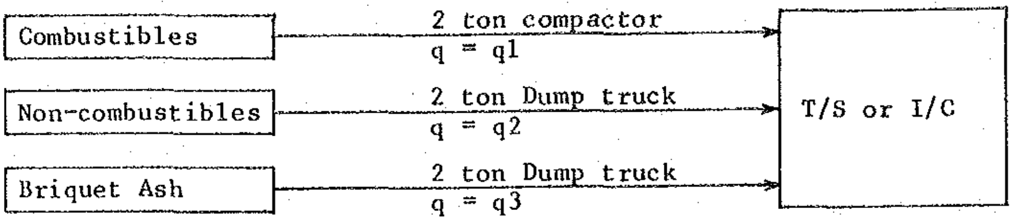
From the viewpoint of fitness for intermediate process, Alt. I (3 components separation) is most desirable in volume reduction and material recovery. Alt. III (combustibles, others) is suitable for only volume reduction, and Alt. II (briquet ash, others) is inadequate for either purpose.

(3) Cost Comparison of the Separation Alternatives

Although it is said that collection costs escalate as the number of separation components increase, the investment and operation/maintenance (O/M) cost of intermediate facilities such as incinerator or recovery equipments can be reduced as the objectives for the purpose of facility has been already sorted out on the collection stages. O/M cost for collection is estimated here.

- Cost Comparison Model

(1) Alt. I (3 components)

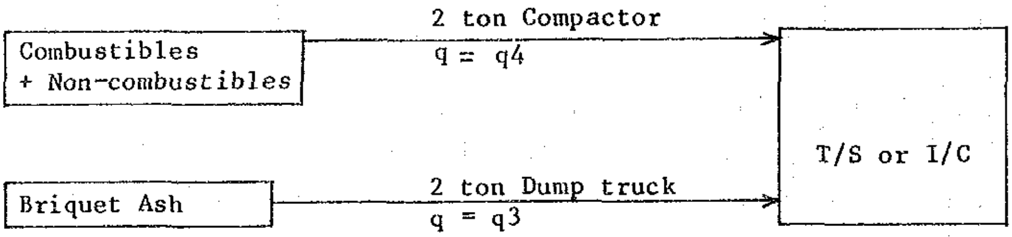


T/S: Transfer Station

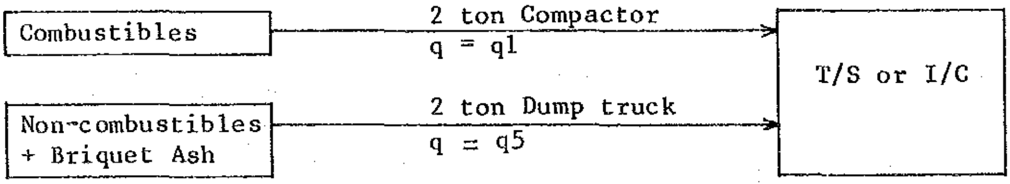
I/C: Incineration plant

q: Effective loading capacity

(2) Alt. II (2 components)



(3) Alt. III (2 components)



- Calculation condition

Daily waste generation amount : Q [t/day]

Combustibles : Q1 ["]

Non-combustibles : Q2 ["]

Briquet ash : Q3 ["]

$Q = Q1 + Q2 + Q3$

Distance between collection site and intermediate facility

: L [km]

Hauling speed : V [km/hr]

Equation for O/M cost

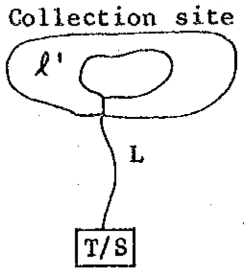
$$\underset{[₩/t/km]}{\text{Cunit}} = \frac{m}{q} + \frac{f \text{ x } o}{q} + \frac{S \text{ x } W + d}{k \text{ x } q \text{ x } \ell} + \frac{V}{k \text{ x } q \text{ x } \ell \text{ x } t \text{ x } u}$$

$$k = \frac{Te}{q \text{ x } (16.7El + Et) + Tt + Td}$$

$$\ell = \ell' + 2 \text{ x } L \qquad Tt = 120 \text{ x } L/V$$

$$\ell' = \frac{1}{60} \text{ x } Et \text{ x } q \text{ x } V'$$

$$C\ O/M = \text{Cunit x } Q \text{ x } \ell$$



Cunit : Unit cost per ton per km

k : Trip number

ℓ : Round trip distance

ℓ' : Collection distance

C O/M : Operation/maintenance cost

* meaning of other symbols is refered to Section 5-5-3.

L = 5 km

V = 30 km/hr.

V' = 10 km/hr.

Te = 420 min (= 7 hr)

El = 1 sec/kg

Et = 4 min/ton

Td = 10 min

Q1 = 0.6 x Q

Q2 = 0.1 x Q

Q3 = 0.3 x Q

Q: Daily waste generation rate [t/d]

Q1: Combustibles [t/d]

Q2: Non-combustibles [t/d]

Q3: Briquet Ash [t/d]

Table 4-2-4 Loading Capacity

	Loading Density	Loading Capacity
q1	0.35 t/m^3	1.4 t/truck
q2	0.3 t/m^3	1.2 t/truck
q3	0.5 t/m^3	2.0 t/truck
q4	0.35 t/m^3	1.4 t/truck
q5	$\frac{0.30xQ2+0.5xQ3}{Q2 + Q3}$	$4m^3$x(Loading Density) t/truck

* Loading volume is $4m^3$ for each Truck

Table 4-2-5 Factor on Vehicle

	2 ton compactor	2 ton Dump truck
v [won/truck]	18,600,000	12,300,000
t [yr]	6	6
u [d/yr]	300	300
m [won/km]	155	68
f [1/km]	0.25	0.17
o [won/1]	270	270
s [won/head/d]	9,500	9,500
w [head]	2	2
d [won/d]	12,500	12,500

The O/M cost for collection is estimated as shown in Table 4-2-6. The result shows that there is not a big difference among the three alternatives. It means that although it is said that collection cost tends to increase in proportion to the number of separation components, the total cost to transport mass from one place to another is the same when conditions such as hauling speed, working hours, and wages are same.

It also shows that, although the conditions set for this calculation do not include factors such as collection frequency and seasonal fluctuation, the collection cost does not affect the choice of separation alternative when appropriate collection planning is made. Thus, the result indicates that selection of separation alternatives should not be determined by cost, but by other factors such as method of intermediate processing.

Table 4-2-6 Cost on Separation Alternatives

	Q [t/d]	q [t/truck]	K [trip/d]	1 = 1'+ 2 x L [km]	Cunit [₩/t/km]	C o/m = Cunit x Q x 1 [₩/d]
Alt. I (1) Combustible (2) Non-Combustible (3) Briquet Ash	I-(1) 0.6 x Q	1.4	7.12	10.93	543	5,250 x Q [1.01]
	I-(2) 0.1 x Q	1.2	7.66	10.80	481	
	I-(3) 0.3 x Q	2.0	5.88	11.33	344	
Alt. II (1) Briquet Ash (2) Others	II-(1) 0.3 x Q	2.0	5.88	11.33	344	5,324 x Q [1.02]
	II-(2) 0.7 x Q	1.4	7.12	10.93	543	
Alt. III (1) Combustible (2) Others	III-(1) 0.6 x Q	1.4	7.12	10.93	543	5,210 x Q [1.0]
	III-(2) 0.4 x Q	1.8	6.24	11.20	368	

(4) Evaluation of Separation Alternatives

Evaluation of separation alternatives is described in Table 4-2-7.

Alt. 1 is the most desirable for incineration and material recovery. Alt. II is not desirable, but should be adopted when citizens' cooperation for 3-component separation is not acquired.
Alt. III is not acceptable, because it is not suitable for material recovery and also inferior to Alt. II in terms of citizens' cooperation.
When Alt. I is adopted, volume reduction effect at the generation source can be expected, because some of the marketable non-combustibles are picked up by private recycle shops.

Table 4-2-7 Evaluation of Separation Alternatives

	Alternative I (Combustibles) (Non-Combustibles) (Briquet Ash)	Alternative II (Briquet) (Others)	Alternative III (Combustible) (Others)
Cooperation of citizens	Relatively difficult	Easy	Relatively difficult
Need for Incineration	Suitable	Unsuitable	Suitable
Need for Material Recovery	Suitable	Unsuitable	Unsuitable
Collection Cost	Same as others	Same as others	Same as others
Evaluation	Optimum	Unwilling	Not acceptable

4-2-2 Collection Improvement

(1) Dwelling Composition

The dwelling compositions in 1983 and 2005 are shown in Fig. 4-2-1.

where,
Weak collection house : Pannier or bell ringing collection
Superior independent house : Road width is over 3.0 m
Old traditional independent house: Road width is less than 3.0 m

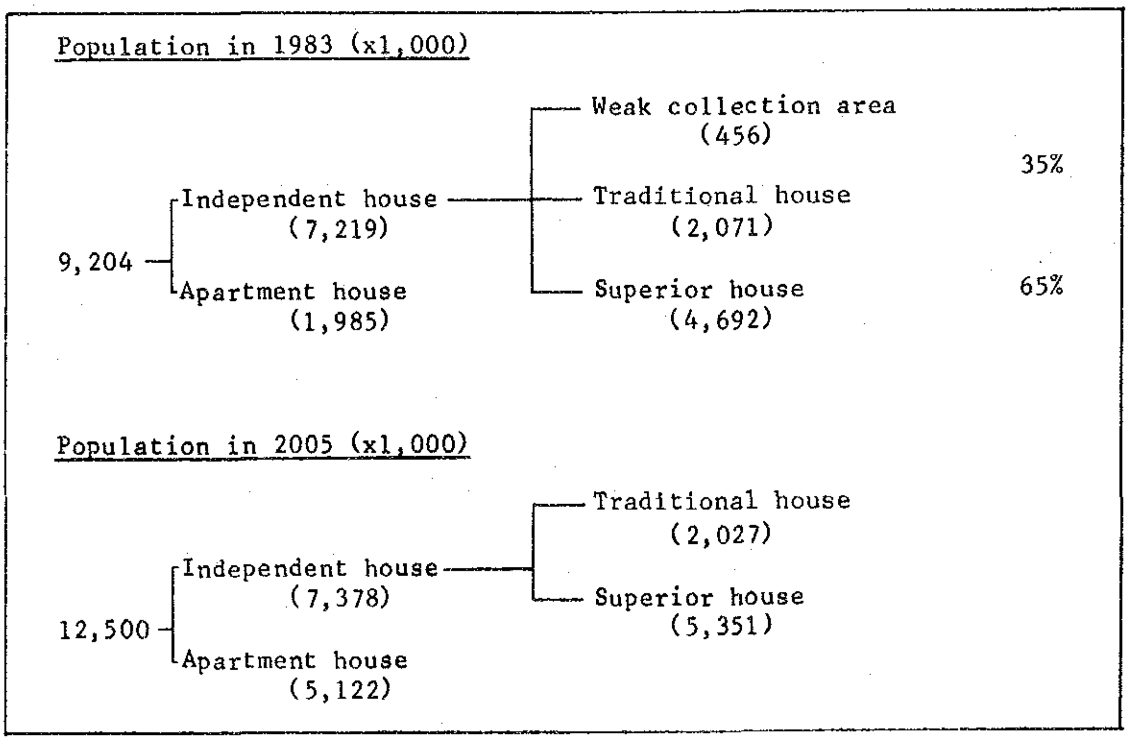


Fig. 4-2-1 Dwelling Composition

Assumptions:

1. Of the increased population of 3,296 thousand, 80 and 20 percent will be distributed to apartments and independent houses, respectively.

2. 500 thousand houses in the weak collection and old traditional independent house areas will be reconstructed into apartment houses.

(2) Discharge Method

1) Existing Waste Discharge Situation and Problems

Waste generation and discharge situation are described in Table 4-2-3. The present system has several problems to be solved. One is that the living environment is affected by odor, leachete, putrescence and flies as garbage is stored unwrapped in a fixed dust box or dust chute pit for several days. Fixed dust boxes and dust chute pits reduce the collection efficiency and intensify the burden of labour.

2) Storage Method

There are several storage methods as shown in Table 4-2-8. The factors to influence the selection of storage method are as follows:

1. Characteristic and amount of waste
2. Easiness to discharge
3. Easiness for collecting
4. Collection method (door to door, station, mechanical loading)
5. Collection efficiency
6. Occupied space

Table 4-2-8 Storage Method

Immovable manually	Concrete box, Container box, Dust box
Movable manually	Polyethylene receptacle, Metal can, Paper bag, Polyethylene bag
Fixed store room	Dust chute pit
Appointed place	Storage shed for bulky waste or recoverable matter

3) Station or Door to Door Collection

Door to door collection is performed in most areas in Seoul. Door to door collection means a high level of service, however, collection effiency is comparatively low. Station collection is highly efficient, however, it requires the citizens to carry waste to the station and to clean there after loading.

In the case of a vehicle collection system, station collection is strongly recommended because of its collection efficiency and mobility of vehicles along curbside.

The interval of the stations is about 50 m in principle. At least 20 m should be kept for collection efficiency, and the maximum distance of 100 m should be kept for citizens' convenience.

4) Discharge Concept

a. Combustibles

When the combustibles including garbage are stored in the existing concrete boxes, an unsanitary situation will occur and collection efficiency will be reduced. To improve these circumustances the following measures are suggested:

- Abolish discharging the combustibles to the existing fixed dust box or dust chute pit and instead, discharge them by using the polyethylene bags for sealing and waterproofing.

- Adoption of station system, e.g. discharge the waste at a station at designated time and day.

b. Non-combustibles

The non-combustibles have less influence on the environment compared to the combustibles.

Generation rate of non-combustibles is less than the other wastes.

- Waste is stored in the existing concrete boxes or in the house by bagging.

- Station system is adopted and waste is discharged at a station at designated time and day.

- Dust chute pit can be utilized in central heated apartment house.

c. Briquet ash

Environmental concern on briquet ash is limited, but some particular storage method is needed. However, there will be objection to change the present door to door system to station system because of its heavy weight and large amount of waste generated.

The station collection is strongly requested due to two points: One is the collection efficiency, and the other is the mobility of collection vehicles along alleys. Because there are many narrow roads in Seoul the collection vehicles can not move from door to door.

In respect to the inconvenience of carrying briquet ash to a station, waste volume to be carried at a time can be reduced in accordance with the collection frequency, and by adoption of container box as will be described afterwards. The following measures are recommended for briquet ash.

- Store the waste in a house or beside a house as has been done.

- Discharge the waste at a station or in a container box.

When briquet ash is loaded manually, workability will be extremely low. To improve the collection efficiency use of a container box is desirable as it fits to handle a large amount of waste (Fig. 4-2-2).

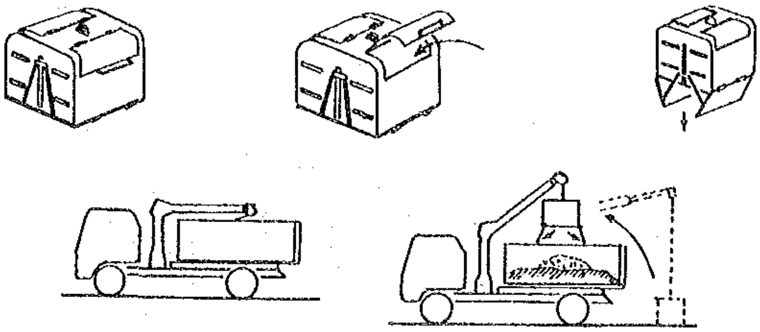


Fig. 4-2-2 Container Box and Loading Situation

The existing collection situation of dust chute pit of apartment house is not good for collection workers as the dust chute pit is located below the ground level without considering sanitation and the convenience for workers.

To improve this situation, dust chutes should be abolished and a station system should be adopted.

Whenever construction of new apartments is planned, it is vital to consider the waste treatment from a structual viewpoint. Recommended storage method based on the dwelling type is summarized in Table 4-2-9.

Table 4-2-9 Recommended Storage Method

Type of House		Storage Method			Description
		Generation	Storage Place	Discharge	
Independent House		Combustibles	Home	Station	Need to discharge with bag or sack
		Non-Combustibles	Home or Existing Concrete Box	Station	Need to discharge with bag or sack. Container Box is more desirable for collection efficienty
		Briquet Ash	Container Box	Container Box	Station is applied if appropriate place for Container Box is not acquired
Apartment House with Dust Chute	Ordinary	Combustibles	Home	Station	Ditto as Independent House
		Non-Combustibles	Home	Station	Ditto as Independent House
		Briquet Ash	Container Box Dust Chute Pit	Container Box Dust Chute Pit	Container Box is desirable however, Dust Chute Pit is acceptable to reduce citizens' burden
	Central Heating	Combustibles	Home	Station	Ditto as Independent House
		Non-Combustibles	Home Dust Chute Pit	Station Dust Chute Pit	Dust Chute Pit is acceptable to reduce citizens' burden
Apartment House without Dust Chute		Combustibles	Home	Station	Ditto as Independent House
		Non-Combustibles	Home or Existing Concrete Box	Station	Ditto as Independent House Existing storage shed can be used as the station
		Briquet Ash	Container Box	Container Box	Existing storage shed can be used as the station, if appropriate place for container Box is not acquired

(3) Collection frequency

Collection frequency is determined based on the amount of waste to be generated and stored by the time of collection.

Collection frequency is also influenced by number of vehicles and workers, and working hours per day. Amount of waste handled on a collection day is calculated and shown in Table 4-2-10. It shows that fluctuation of treated amount of waste tends to increase as collection frequency increases. For uniformity of treated amount of waste, it is better to minimize the collection frequency although it is inconvenient for citizens.

Collection frequency of each waste is considered as follows in accordance with its charateristics:

1) Combustibles

Interval of collection is required to consider preservation of living environment from nuisance of putrefaction and swarming of flies.

Waste is better to be discharged in two or three days in respect of oder or putrefaction. Generation of flies can be also prevented by frequent collection as it takes at least 5 days for them to hatch.

Table 4-2-10 Variation of Collected Waste

Collection frequency [time/week]	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.	Sun.	Note
1	A-7Q	B-7Q	C-7Q	D-7Q	E-7Q	F-7Q	--	dmax = 7 [days]
	7Q	7Q	7Q	7Q	7Q	7Q	--	= 42Qton
2	A-4Q D-4Q	B-4Q E-4Q	C-4Q F-4Q	A-3Q D-3Q	B-2Q E-3Q	C-3Q F-3Q	--	dmax = 4 [days]
	8Q	8Q	8Q	6Q	6Q	6Q	--	= 42Qton
3	A-3Q C-3Q E-3Q	B-3Q D-3Q F-3Q	A-2Q C-2Q E-2Q	B-2Q D-2Q F-2Q	A-2Q C-2Q E-2Q	B-2Q D-2Q F-2Q	--	dmax = 3 [days]
	9Q	9Q	6Q	6Q	6Q	6Q	--	= 42Qton
4	A-2Q A-2Q C-2Q D-2Q E-2Q F-2Q	A-1Q B-1Q C-1Q D-1Q	E-2Q F-2Q	A-2Q B-2Q C-2Q D-2Q	E-2Q F-2Q	A-2Q B-2Q C-2Q D-2Q E-1Q F-1Q	--	dmax = 2 [days]
	12Q	4Q	4Q	8Q	4Q	10Q	--	= 42Qton
5	A-2Q B-2Q C-2Q D-2Q E-2Q F-2Q	B-1Q C-1Q D-1Q E-1Q	A-1Q C-1Q D-1Q E-1Q F-1Q	A-1Q B-1Q D-1Q E-1Q F-1Q	A-1Q B-1Q C-1Q E-1Q F-1Q	A-1Q B-1Q C-1Q D-1Q F-1Q	--	dmax = 2 [days]
	12Q	4Q	5Q	5Q	5Q	5Q	--	= 42Qton
6	A-2Q B-2Q C-2Q D-2Q E-2Q F-2Q	A-1Q B-1Q C-1Q D-1Q E-1Q F-1Q	A-1Q B-1Q C-1Q D-1Q E-1Q F-1Q	A-1Q B-1Q C-1Q D-1Q E-1Q F-1Q	A-1Q B-1Q C-1Q D-1Q E-1Q F-1Q	A-1Q B-1Q C-1Q D-1Q E-1Q F-1Q	--	dmax = 2 [days]
	12Q	6Q	6Q	6Q	6Q	6Q	--	= 42Qton

Remarks: Collection area is divided into 6 districts (A-F).

Each district generates Q ton/day of waste, dmax shows the maximum interval days to be stored.

Collection is not performed on Sunday.

Thus collection frequency is standardized here; 3 times/week. It can be adjusted depending on seasonal fluctuation and local conditions. Amount of waste to be stored in 2005 is calculated by the following formula:

$$V = \frac{Q \times N \times D}{q} = 38 - 57\ (\ell/\text{household})$$

where, V : Stored amount of waste

Q : Per capita generation rate (=1.258 kg/head/day)

N : Number of persons per houshold (=4.5 head/household)

D : Stored days (=2 - 3 days)

q : Unit bulk density (=0.3 ton/m^3)

2) Non-combustibles

It will be possible to store non-combustibles for over a week because of its small amount of generation and scarcity on pollution compared to combustibles. However, disharge and collection should be performed within a week considering unpleasantness and unaesthetic appearance of waste.

Thus, the collection frequency is standardized here; Once a week Amount of waste to be stored is calculated as follows:

$$V = \frac{Q \times N \times D}{q} = \frac{0.253 \times 4.5 \times 7}{0.3} = 27\ (\ell/\text{household})$$

3) Briquet ash

Briquet ash is stored in a dust chute pit or container box. Collection frequency of dust chute pit should be regulated depending on number of occupants, capacity of pit and generation rate. Capacity of a container box is normally 0.4 m^3 and 0.6 m^3. Collection frequency is determined in relation to the capacity of box and number of house hold.

If one container box covers 20 households, possible interval day is calculated as

$$Id = \frac{v}{Q \times N \times n \div q} = \frac{600\ (400)}{0.596 \times 4.5 \times 20 \div 0.5} = 5\ (4)\ [days]$$

where, v : Capacity of container box (=600 or 400 l)
n : Number of households (=20)

and collection frequency is

1 - 2 times/week

If it covers 40 households, possible interval day is

Id = 3 (2) [days]

and collection frequency is

3 - 4 times/week

Where container box can not be set out due to road conditions or difficulty of land acquisition, station method is performed.

In the case of a station system, collection frequency is regulated in accordance with the amount of waste to be carried at a time.

Possible interval day is calulated on assumption of acceptable carriage weight of 5 - 7 kg at maximum.

$$Id = \frac{W}{Q \times N} = \frac{5 - 7}{0.596 \times 4.5} = 2 - 3\ [days]$$

where, W : carriage weight at a time (=5 - 7 kg)

and collection frequency is

3 - 4 times/week

Seasonal fluctuation of briquet ash is so great that collection frequency should be changed accordingly.

Collection frequency of each kind of waste is standardized here as summarized in Table 4-2-11.

Table 4-2-11 Adequate Collection Frequency of Each Waste

Waste	Collection Frequency
Combustibles	3 times/week (station)
Non-Combustibles	1 time/week (station)
Briquet Ash	1 - 4 times/week (container box*)
	3 - 4 times/week (station)

*): Depend on the capacity of box and number of households.

The amount of waste to be collected fluctuates as collection frequency changes as shown in Table 4-2-10. When the waste is collected only once a week, the daily collection amount is 7Q. When it is collected every day except Sunday, the amount is 6Q from Tuesday to Friday, and 12Q has to be collected on Monday. This means that the number of collection workers has to be doubled on Monday if the working hour is fixed. Thus, to minimize the fluctuation of work load, the waste should be collected every day including Sunday as shown in Table 4-2-12. The collection frequency should be studied in conjunction with the number of districts.

Table 4-2-12 Variation of Collection Frequency and Number of District

a. 6 days/week - 6 districts

Area	Collection Day							Total
	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.	Sun.	
A	4			3				7
B		4			3			7
C			4			3		7
D	4			3				7
E		4			3			7
F			4			3		7
	8	8	8	6	6	6	0	42

b. 7 days/week - 7 districts

Area	Collection Day							Total
	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.	Sun.	
A'	3.4			2.6				6
B'		3.4			2.6			6
C'			3.4			2.6		6
D'				3.4			2.6	6
E'	2.6				3.4			6
F'		2.6				3.4		6
G'			2.6				3.4	6
	6	6	6	6	6	6	6	42

To standardize the amount of waste to be collected, the area should be divided into 7 districts in this case. Then the daily collection amount becomes 6Q from Monday to Sunday. The size of each district is reduced and the daily waste collection rate is reduced from 7Q to 6Q.

The size of each district, collection frequency of each component, and seasonal fluctuation should be studied in the detail planning of collection method.

(4) Introduction of Vehicle Collection

1) Problems of Hand Cart Collection and Requirement of Vehicle Collection

Most waste is collected by hand carts at present in Seoul. There are several problems with this system as listed below:

- Laboriousness for collection workers.
- Danger of traffic accidents, slipping in winter, falling into truck at transfer station, etc.
- Irregular collection efficiency and physical load caused by weather.
- Unsanitary condition; leachate, odor, scattering of the waste, etc.
- Unaesthetic appearance

To solve these problems, vehicle collection is recommended for the following reasons;

- It alleviates the burden of the work, and makes for efficient collection.
- Easy protection against environmental pollution by compactor truck, covered dump truck, container box, etc.
- Less influence by climate conditions
- Safety from traffic accident
- Reduction of the collection cost (c.f. subsection 4-2-4)

2) Vehicle Assignment

There are several types of vehicle used for different purposes. Selection depends on waste characteristics, purpose of intermediate facilities, collection efficiency, road width, etc.

In general, the larger the capacity of the vehicle, the higher the collection efficiency as collection cost is lowered.

In Seoul, the following types of vehicle are recommended based on the waste charactaristics, loading efficiency and environmental preservation.

- The compactor trucks for combustibles, for sealing odor and leachate, a large volume of waste by compaction, easy loading by its low position of inlet (Fig. 4-2-3).

- The dump trucks are basically used for non-combustibles and briquet ash, judged from incommpressibility and less influence on sanitation of the waste.

As the beds of ordinary dump trucks are high, it is rather hard to toss waste onto trucks. To improve loading efficiency, use of attached crane is recommended for its simplicity and easiness for installation. There are two ways of using the crane according to the discharge style of waste: stations and container boxes.

For collecting the bagged wastes at the station, use of a crane to hoist bucketed waste is recommended (Fig. 4-2-4).

For collecting the contained waste, hooking the box and craning it onto trucks is recommended (Fig. 4-2-2). In both cases, covering the top of truck is required to prevent the waste from spilling.

As to the capacity of trucks, the larger its capacity the better the collection efficiency as described above. Its size is defined taking into consideration the road width, traffic volume and hauling distance.

There are many branch lanes, narrow and congested roads in Seoul, so a 2 ton truck is recommended, and 4 ton truck is applicable for large volume dischargers such as apartment house and commercial area, and for the area whose road width is over 6m.

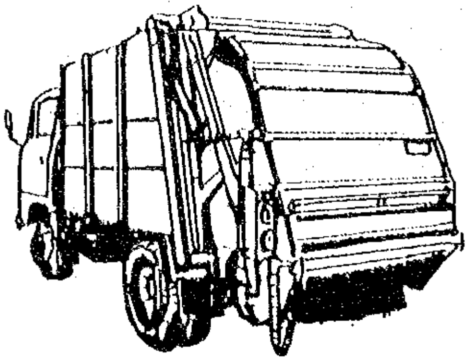


Fig. 4-2-3 Compactor Truck

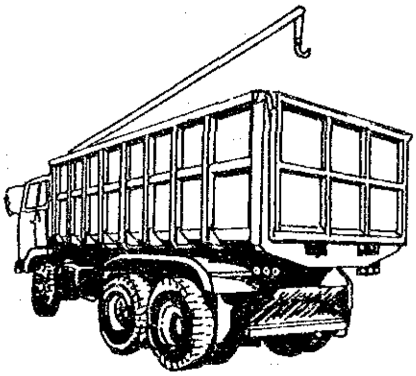


Fig. 4-2-4 Dump Truck with Crane

4-2-3 Consideration of Transfer/Transportation System

(1) Purpose of Transfer Station

The main purpose of setting up a transfer station is to reduce the transportation cost and number of transportation vehicles to the disposal site.

Advantages and problems of the transfer station system are shown in Table 4-2-13.

Table 4-2-13 Advantages and Problems of Transfer Station

Advantages	Problems
1. Decrease in labor cost of workers. . Direct haul driver + collection workers . Transfer station ... driver	1. Difficulty of land acquisition for transfer station
2. Larger quantity transportable	2. Requirements for environmental preservation of noise, odor and leachate
3. Decrease in number of collection vehicles	3. Concentration of collection and transportation vehicles
4. Even when the location of the final disposal site is changed, change of collection plan is not required	

Transfer and transport operations become a necessity when haul distances to available disposal sites or processing centers are increased to the point that direct hauling is no longer economically feasible. Simply stated, it is cheaper to haul a given volume of waste a few times in large increments than to haul a given volume of waste several times in small increments over a long distance.

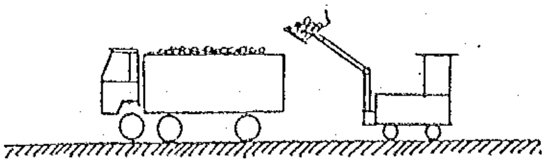
In 2005, disposal site will be in Incheon, about 30 km away from Seoul City, and as break-even-distance (a distance which cost of direct haul is equal to that of collection and tansportation through transfer station) is less than 30 km as calculated in the following section. Thus, transfer system is economical and desirable.

(2) Transfer Methods

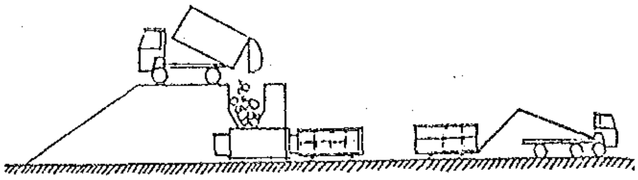
Five types of transfer stations are shown in Table 4-2-14 and Fig. 4-2-5 , respectively.

Table 4-2-14 Transfer Station

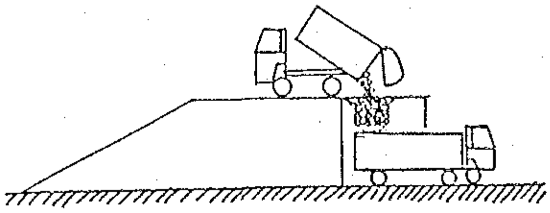
Method	Description
Common Method	Solid waste is transferred from collection car to dump truck by bucket loader or crane with bucket
Common Method with Hopper	Solid waste is dumped from collection car to dump truck through hopper
Pit and Crane Method	Solid waste is dumped from collection car to storage pit and is transferred to dump truck through hopper by crane with bucket
Compactor Container Method	Solid waste is packed in a closed container by compacting equipment
Container Transfer Method	Solid waste is collected by container collection car (1.0 m^3), and only the container is transported



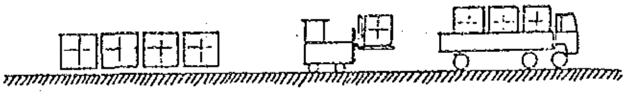
Common method



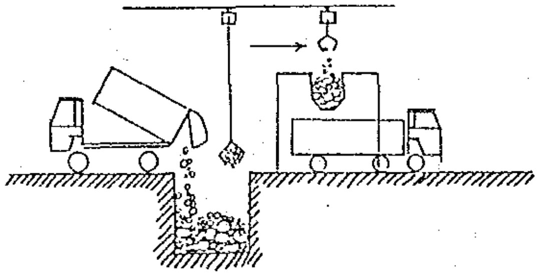
Compactor container method



Common method with hopper



Container transfer method



Pit and crane method

Fig. 4-2-5 Transfer Station

To choose the transfer method, the following factors are considered.

- Transferring efficiency, cost, maintenance, reliability environment, etc.

Comparison of each method summarized in Table 4-2-15 shows that the common method with hopper is desirable with respect to transferring efficiency, maintenance and reliability of facilities.

View of the common method transfer station with hopper is illustrated in Fig. 4-2-6.

Table 4-2-15 Evaluation of Transfer Method

	Common method	Common method with hopper	Pit and crane method	Compactor container method	Container transfer method
Equipment	. Bucket loader . Crane with bucket . Clamshell	. Guide hopper . Bucket loader	. Crane with bucket . Clamshell . Hopper	. Compactor . Hopper . Container	. Forklift . Container
Mechanism & stability	Simple & High	Simple & High	Simple & High	Complex & a little low	Simple & High
Maintenance	Easy	Easy (Need to control the traffic route)	Average (Need a spare crane or clamshell)	A little difficult (Anxious about trouble with compactor)	Easy
Efficiency	Average	High	High	High	High
Flexibility for wastes fluctuation	Possible (Need a storage space)	Possible (Need a storage space)	Possible (Need a large volume pit)	A little low (Depend on ability of compactor)	Possible (Need a large number of containers
Sanitary conditions	Need some prevention (odor, scattering)	Need some prevention (odor scattering)	Need some prevention (odor scattering leachete)	Good (Concern about Noise of compressor)	Good
Investment cost	Low	Average	A little high	High	Average (Include containers)
Operation/maintenance cost	Low	Low	Low	Average	Low
Evaluation	Acceptable (Simple)	Optimum	Average	Not acceptable (Expensive)	Not acceptable (Need to change collection system)

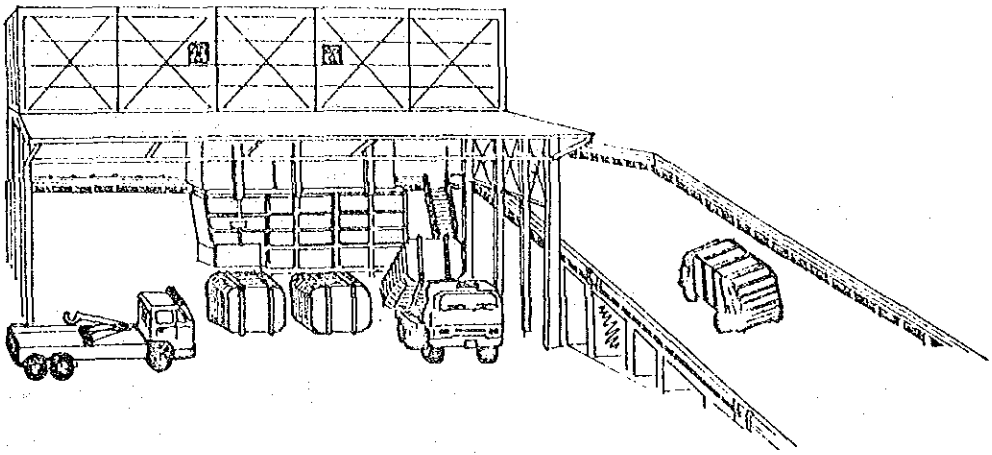


Fig. 4-2-6 View of the Transfer Station
(common method with hopper)

(3) Transportation Vehicles

Vehicles for transportation from transfer station to disposal site are needed to carry efficiently a large amount of waste. There are two types of vehicles commonly used: one is an ordinary dump truck and the other is a container.

The transporting efficiency of the container system is extremely high, because waste can be dumped into a container while a truck is hauling another container to a disposal site. Thus, container system is recommended for its transportation efficiency.

As a larger container has larger efficiency, the capacity of 10 ton (means 20 m^3 box) container is recommended, as this size is commonly used and easy to purchase. Two container boxes should be provided for a container truck in order to be efficient.

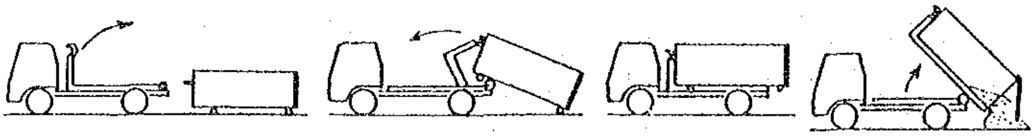


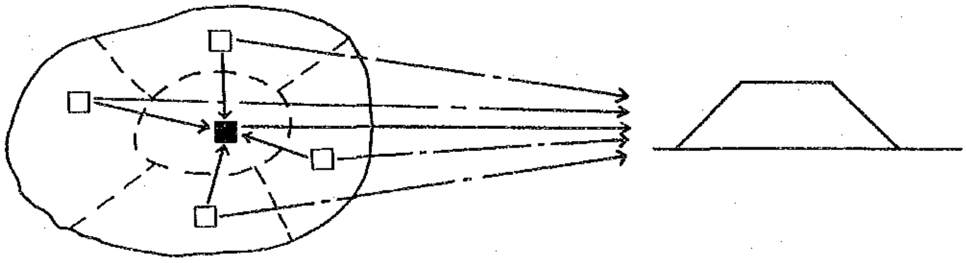
Fig. 4-2-7 Container Truck

(4) Appropriateness of Transfer/Transportation System

The transfer system becomes more economical than the direct haul system when the transport distance is greater than the "break-even distance," where the cost of direct haul is equal to the cost of transfer/transportation.

The formulas to obtain the costs of collection, transport and transfer station are described herein.

- Comparison model



◯ : Collection area

⬚ : Area for one collection vehicle

■ : Transfer station

→ : Route of transfer/
transportation system

-·-→ : Route of direct haul system

⏢ : Disposal site

Remarks: Average haul distance by direct haul system and distance from T/S to disposal site by transfer/transportation system is considered to be equal as T/S is located at the centre of collection area.

- Calculation equation

$C = Cunit \times 1$

C : Hauling cost [₩/ton]
1 : Haul distance include collection & transportation [km]

$$Cunit = \frac{m}{q} + \frac{f\ o}{q} + \frac{2S + d}{k \times 1 \times q} + \frac{v}{k \times 1 \times q \times t \times u}$$

Remarks: Meaning and value of each symbol are described in Section 5-5-3.

Direct haul system

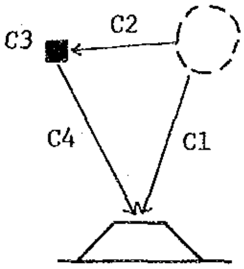
- Transportation cost for direct haul system (₩/ton) : $C1 = a_1L + b_1$

Transfer/transportation system

Collection cost (₩/ton) : C2

Operation cost for transfer station (₩/ton) : $C3 = A + \frac{B}{X}$

Transportation cost for transfer station system (₩/ton) : $C4 = a_2L + b_2$



where,

L : Haul distance (km).
X : Capacity of transfer station (ton/day).
a, b : Coefficient related to transport and collection vehicles, such as labor costs for workers, purchase costs for vehicles, maintenance costs for vehicles and fuel costs.
A, B : Coefficient related to transfer station, such as land acquisition costs, costs for civil works, equipment costs and maintenance costs.

- Calculation condition

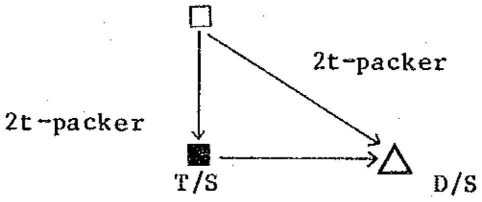
- Distance from collection site to T/S is assumed to be 5 km.
- Bulk density for combustibles on loading is 0.35 [t/m^3].
- Bulk density for non-combustibles and briquet ash is 0.45 [$5/m^3$].

The unit costs of C1, C2, C3 and C4 for each type of vehicle are obtained from formulas of parameters, and shown in Table 4-2-16.

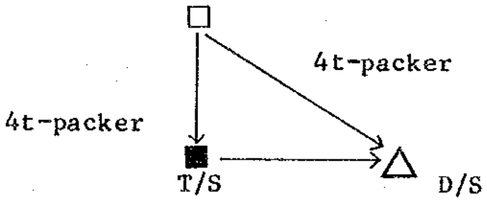
Table 4-2-16 Unit Cost (C)

Case	Kind of Vehicle	C1	C2	C3	C4
1	2 ton packer car for combustible waste	602xL + 3,627	6,650	$660 + \frac{17,840}{Q}$	152xL + 570
2	4 ton packer car for for combustible waste	343xL + 3,067	4,786	"	152xL + 570
3	2 ton dump truck for non-combustible waste & briquet ash	329xL + 2,980	4,617	"	100xL + 380
4	4 ton dump truck for non-combustible waste & briquet ash	231xL + 2,770	3,924	"	100xL + 380

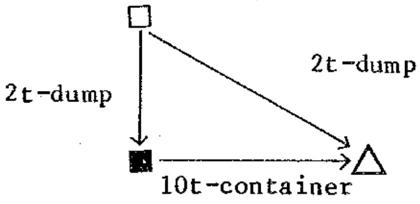
Case 1 (Combustible)



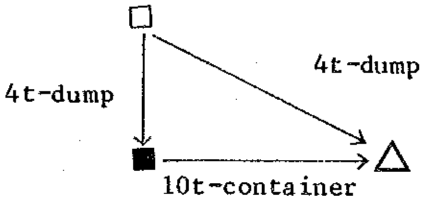
Case 2 (Combustible)



Case 3 (Non-combustible
Briquet ash)



Case 4 (Non-combustible
Briquet ash)



The "break-even distance" (L) for 4 cases is obtained from the following formula:

$C1 = C2 + C3 + C4$

Case 1

2 ton packer car: $L = 9.5 + \frac{39.6}{X}$ .... (1)

Case 2

4 ton packer car: $L = 15.4 + \frac{93.4}{X}$ .... (2)

Case 3

2 ton dump truck: $L = 11.7 + \frac{77.9}{X}$ .... (3)

Case 4

4 ton dump truck: $L = 16.7 + \frac{136.2}{X}$........ (4)

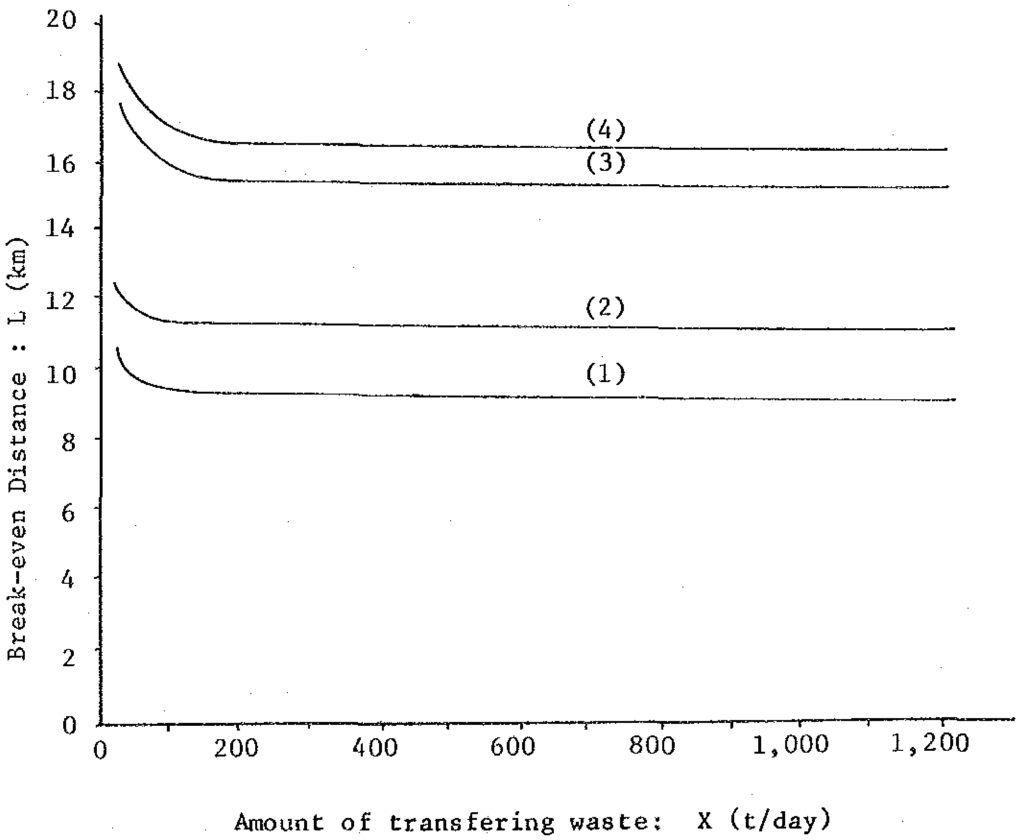


Fig. 4-2-8 Break-even Distance