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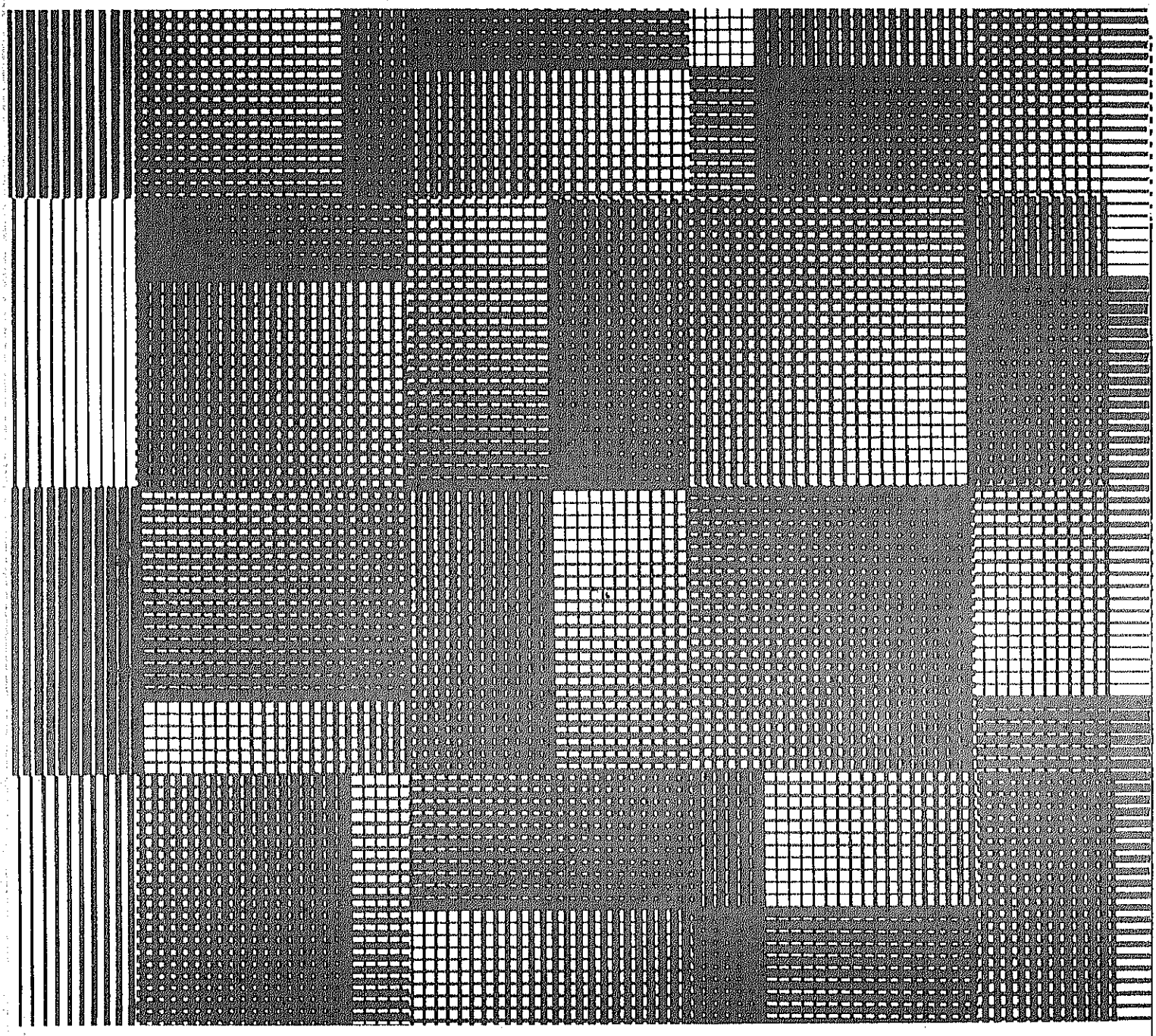
NO. 8

KINGDOM OF THAILAND

THE BANGKOK SOLID WASTE MANAGEMENT STUDY

FINAL REPORT



SEPTEMBER, 1982

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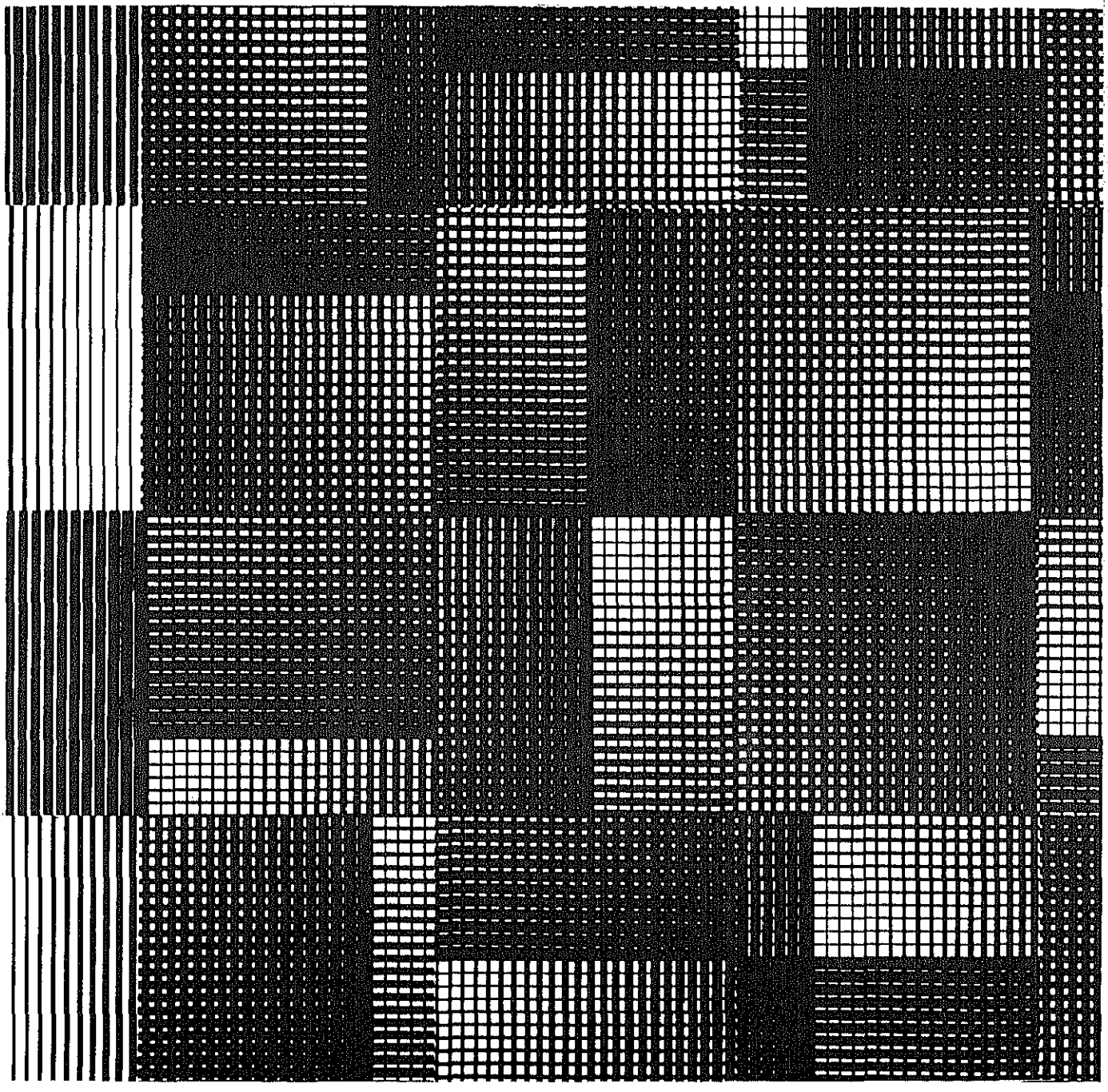

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PREFACE

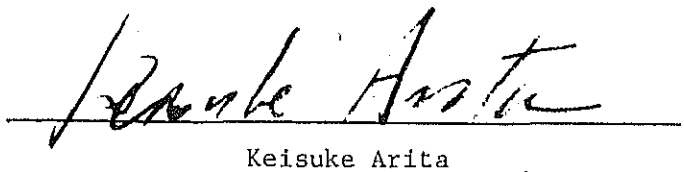
In response to the request of the Government of the Kingdom of Thailand, the Japanese Government decided to conduct a study on the solid waste management project in Bangkok Metropolitan Area and entrusted the study to the Japan International Cooperation Agency.

The JICA sent to the Kingdom of Thailand a study team headed by Mr. Jiro Yamai from June 1980 to February 1981 and from November 1981 to December 1981 respectively. The team exchanged views with the officials concerned of the Government of Thailand and conducted a field survey. After the team returned to Japan, further studies were made and the present report has been prepared.

I hope that this report will serve for the development of the project and contribute to the promotion of friendly relations between our two countries.

I wish to express my deep appreciation to the officials concerned of the Government of the Kingdom of Thailand for their close cooperation extended to the team.

September, 1982



Keisuke Arita
President
Japan International Cooperation Agency

ABBREVIATIONS

a	:	are (100 m^2)
฿	:	Baht
B/C	:	Benefit-Cost Ratio
BE, B.E.	:	Buddhist Era (2523 = 1980)
BMA	:	Bangkok Metropolitan Administration
BOD	:	Biological Oxygen Demand
BOF	:	Bureau of Finance. Present Department of Finance
BOS	:	Bureau of Sanitation. Present Department of Public Cleansing
BSD	:	Bureau of Sewerage & Drainage. Present Department of Sewerage & Drainage
BSW	:	Bureau of Social Welfare. Present Department of Social Welfare
C	:	Compactor (also abbreviation)
CBD	:	Central Bangkok Districts
CIF	:	Cost, Insurance & Freight
C/N	:	Carbon-Nitrogen ratio
COD	:	Chemical Oxygen Demand
Compactor	:	Truck with compacting equipment
CV	:	Coefficient to variance = S.D. ÷ mean x 100
DOF	:	Department of Finance. Former Bureau of Finance
DOPC	:	Department of Public Cleansing. Former Bureau of Sanitation
DPP	:	Department of Policy Planning
DSD	:	Department of Sewerage & Drainage. Former Bureau of Sewerage & Drainage
DSW	:	Department of Social Welfare. Former Bureau of Social Welfare
DTCP	:	Department of Town & Country Planning
EC	:	Electrical Conductivity
EGAT	:	Electricity Generation Authority of Thailand
EIA	:	Environmental Impact Assessment
EP	:	Electric Pricipitator
F/C	:	Foreign Currency Cost Portion
FDF	:	Forced Draft Fan
FRP	:	Fiber Reinforced Plastic
FY	:	Fiscal Year (Oct. 1 to Sept. 30)
GCD	:	Garbage Collection Division, DOPC
GPP	:	Gross Provincial Products
GDP	:	Gross Domestic Products
ha	:	Hectare (10,000 m^2)
IDF	:	Induced-draft Fan
IRR	:	Internal Rate of Return
JICA	:	Japan International Cooperation Agency
Khlong	:	Canal
L	:	Liter
L/C	:	Local Currency Cost Portion
m	:	Meter
MD	:	Mechanical Division, DOF
MEA	:	Metropolitan Electricity Authority
MOAC	:	Ministry of Agriculture and Co-operatives
MOD	:	Ministry of Defence
MOF	:	Ministry of Finance

MOI	:	Ministry of Industry
MOInt.	:	Ministry of Interior
MOPH	:	Ministry of Public Health
MSTE	:	Ministry of Science, Technology and Energy
N-C, NC	:	Collection truck without compacting equipment
NEB	:	National Environment Board
NEC	:	National Environment Committee
NESDB	:	National Economic & Social Development Board
NESDP	:	National Economic & Social Development Plan (5th = 1982 - 86)
NHA	:	National Housing Authority
Non-compactor	:	Truck without compacting equipment
NOx	:	Nitrogen Oxydes
NPV	:	Net Present Value
PCB	:	Polychlorinated biphenyls
PEA	:	Provincial Electricity Authority
Phon	:	Unit of sound level
ppm	:	Parts per million
PPP	:	Polluter's Pay Principle
rai	:	Unit of area (1 rai = 1,600 m^2)
R/C	:	Revenue-Cost Ratio
R-C	:	Difference between Revenue (R) and Cost (C)
S.D.	:	Standard Deviation
SOx	:	Sulphur Oxydes
SPM	:	Suspendid Particulate Material
SS	:	Suspended Solid
SUO	:	Slum Upgrading Office, NHA
The Study team	:	The Bangkok Solid Waste Management Study Team, JICA
TMG	:	Tokyo Metropolitan Government
T-N	:	Total Nitrogen
W/O	:	Without-project case
$\bar{x}$	:	Mean

SUMMARY

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SUMMARY OF DRAFT FINAL REPORT

I Foreword

(1) The objectives and scope of the Bangkok Solid Waste Management Study

The Bangkok Solid Waste Management Study (referred to as the Study) was performed aimed at establishment of plans to solve the problems related to solid waste management in Metropolitan Bangkok, and to realize improvement in public health and protection of the living environment for its citizens. The term of the Study was 28 months from June, 1980 to September, 1982.

The objectives for solid waste management by the Bangkok Metropolitan Administration (BMA) are, first, to ensure a "clean Bangkok" and, second, to utilize city compost effectively. In addition to these goals the Study team considered other objectives as the bases for the Study. These objectives are: 1) total volume collection, 2) total volume treatment and disposal, 3) establishment of a reliable solid waste management system, and 4) promotion of citizen cooperation.

The target year for the Study was fixed as the year 2000 and the objective areas were limited to 24 districts in Bangkok city.

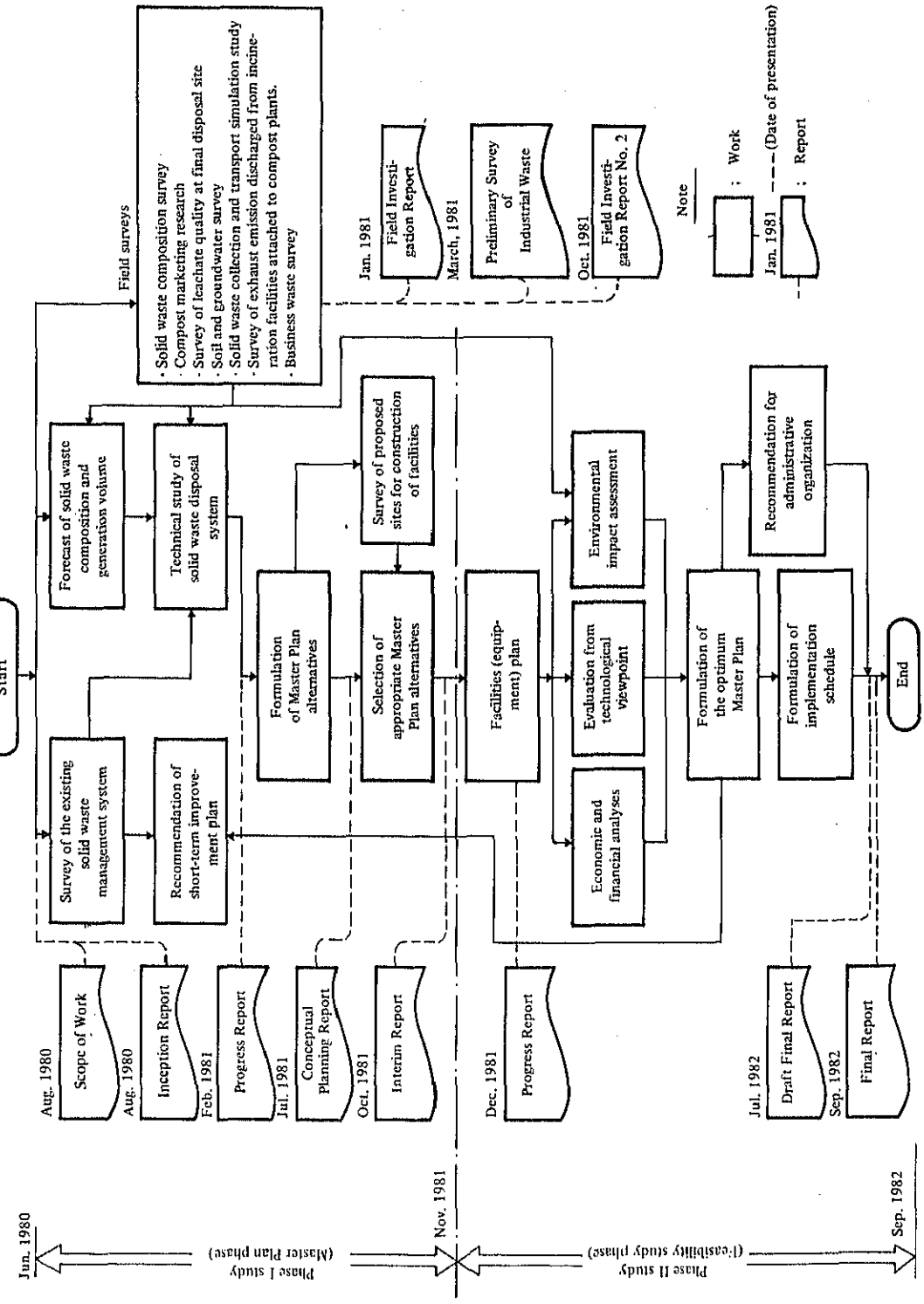
(2) Process of the Study

The Study consists of two phases; Phase I for formulation of the Master Plan and Phase II for the feasibility study. The major work items completed in the Phase I study were a survey of the existing solid waste management system, formulation of a short-term improvement plan, and surveys to collect basic data required for formulation of a long-term Master Plan for the year 2000.

In the Phase II Study, the optimum Master Plan was established and recommendations for the administrative organizations and services were formulated to provide important and useful knowledge for implementation of the Master Plan.

The work flow for the Study is illustrated in Fig. 1.

Fig. 1 The study work flow (Ref: Fig. 1.1)



II Recommendation of Short-term Improvement Plan

(1) Short-term improvement plan

As a result of the field survey of the existing solid waste management system in Bangkok city, many problems were revealed, which vary from minor obstacles to serious problems that cannot be easily solved. From among these, the problems to be urgently solved were evaluated and screened based on consideration of whether or not the problems could be solved or improved under the existing administrative and financial conditions of BMA. For each of the problems so evaluated, countermeasures for solution or improvement were established as a short-term improvement item. The short-term improvement plan consists of 67 short-term improvement items tabulated in Table 1. The short-term improvement plan is assumed to be implemented during the 5-year period from fiscal 1982 to 1986.

Short-term improvement items were classified into the following three categories based on the urgency for implementation of the respective items.

a. Items to be implemented immediately ..... referred to as (I)

b. Items to be implemented step by step ..... (S)

c. Items for which implementation is recommended ..... (R)

Table 1 List of short-term improvement items

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

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

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

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

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

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

(2) Investment cost for the short-term improvement plan

Cost required for implementation of the short-term improvement plan for each year except 1982 is shown in Table 2 next page. The cost for fiscal 1982, which is the first year of implementation, is not included in the table since some of the improvement items have already been initiated.

Table 2 Short-term improvement investment plan

(Unit: 1,000 Baht)

Currency \ Fiscal year	1983	1984	1985	1986
Foreign currency	51,360	57,670	53,800	62,400
Local currency	34,205	47,255	73,455	72,605
Total	85,565	104,925	127,255	135,005
			Grand Total	452,750

Note:· (R) items totalling 40,245,000 Baht are excluded from the figures.

. The investment cost does not include ordinary expenditures.

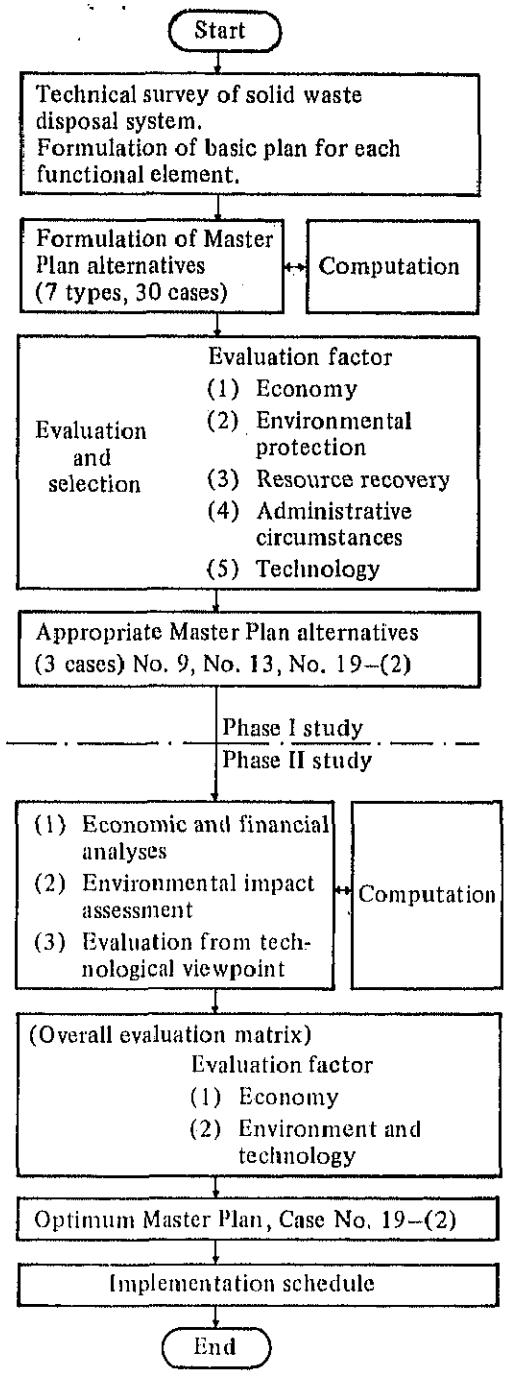
. The breakdown is shown in the Final Report Table 3.11.

III Proposal for the Optimum Master Plan

(1) Formulation of the optimum Master Plan

The optimum Master Plan was formulated based on the Study work flow shown in Fig. 2.

Fig. 2 Study work flow



[Note: For details, refer to Figures 4.1, 4.22 and 8.1 of the Final Report]

The first step of the Study was to collect basic data and information through miscellaneous surveys concerned with the existing solid waste management system (i.e., solid waste composition, natural and socio-economic conditions related to solid waste management, and so forth). Based on the collected data and information, the solid waste composition and generation volume for the future were forecast and, subsequently, a technical study was performed on various types of existing solid waste management technology to determine whether or not they were applicable to the forecast future solid waste conditions. Taking all the results obtained through these surveys and evaluations into consideration, basic plans of individual functional elements (solid waste collection, transport, intermediate treatment and final disposal) were formulated, which established the system to be adopted, required man power and equipment, outline of the facilities and capacity, and the estimated cost.

The basic plan for each functional element was combined with that of other functional elements in seven types of basic solid waste management systems, which were further developed into 30 cases of Master Plan alternatives according to the case of with- or without-transfer stations and with differing numbers of intermediate treatment facilities.

All data and information for the 30 Master Plan alternatives were input into a computer for 'collection and transport simulation'. As a result of the computation, several pieces of essential information were obtained, such as collection and transportation cost for each case, costs related to the facilities for each case, solid waste disposal cost per ton, solid waste transport plan which minimizes these costs, and location and capacity of transfer stations and intermediate treatment facilities.

Evaluation was made on the output from the economic viewpoint and four other factors, and three appropriate Master Plan alternatives were selected from among the 30 cases.

In the Phase II Study, economic and financial analyses and environmental impact assessment were performed on the appropriate Master Plan alternatives with an accuracy equivalent to that in a feasibility study. In addition to these analyses and assessment, evaluation from technological viewpoint was made, which also involved evaluation from philosophical and political viewpoints.

Based on these analyses, assessments and evaluations, an optimum Master Plan was finally selected. Subsequently, an implementation schedule for the optimum Master Plan was formulated and the Study was considered complete at this point.

(2) Forecast solid waste collection plan

The solid waste collection volume was planned to be increased from 2,250 t/d in fiscal 1983 to 5,540 t/d in the year 2000 with a raise of the collection percentage from the current 82% to 97%. Increase rate of solid waste generation volume in the meantime was forecast to drop from 4.8% to 4.1%. The summary of collection plan is shown in Table 3.

Table 3 Forecast solid waste collection plan, 1983-2000 (Ref: Table 2.14)

Fiscal Year	Generation Volume (t/d)	Average Annual Growth Rate (%)	Collection Volume (t/d)	Collection Percentage (%)
1983	2,740	-	2,250	82
1985	3,010	4.8	2,470	82
1990	3,810	4.8	3,310	87
1995	4,670	4.2	4,300	92
2000	5,710	4.1	5,540	97

The solid waste collection volume noticeably increases on Saturdays and Sundays by 10 to 20% compared with an average daily collection volume. The maximum fluctuation per month is 1.09 times as much as the average volume per month.

The total solid waste generation volume in Bangkok city for the future was estimated from a comprehensive analysis of data such as survey results of solid waste generation volume, statistics of solid waste collection volume, and socio-economic indices (GPP, population, land use, etc.), whereas the generation volume for each district in the future was estimated from the relationship with the forecast population by district and forecast land use in each district.

Solid waste physical and chemical composition in the future was estimated on assumption that the current relationship between the composition and material consumption is maintained in the future.

The results of forecast are shown in Table 4.

Table 4 Forecast of solid waste physical and chemical composition in the future (Ref: Table 2.18 and 19)

Chemical composition		Year 1980	Year 2000
Three main components (wt%)			
Moisture content		57.1	55.4
Ash content		15.7	15.7
Combustibles content		27.2	28.9
Total		100.0	100.0
Chemical element composition of wet solid waste (wt%)	C	15.00	16.07
	H	2.26	2.45
	N	0.35	0.34
	O	9.32	9.74
	S	0.06	0.06
	Cℓ	0.23	0.26
	Total	27.22	28.92
Lower calorific value (kcal/kg. wet basis)		1,130	1,280

Physical composition (wt% on wet basis)		Year 1980	Year 2000
1. Combustibles		83.9	83.9
	Paper	18.3	22.1
	Textile	3.6	4.4
	Garbage	29.9	27.6
	Grass and wood	23.2	19.4
	Plastics	7.5	9.2
	Rubber & Leather	1.4	1.2
2. Incombustibles		10.3	10.0
	Ferrous metal	2.0	2.2
	Non-ferrous metal	0.1	0.1
	Glass	2.4	2.6
	Stones & Ceramics	2.4	2.0
	Bones, Shells, Crusts	3.2	3.0
	Dry Cells	0.2	0.1
3. Miscellaneous		5.8	6.1
4. Total		100.0	100.0
Bulk density (in reception pit)		0.29	0.28

(3) Evaluation methods and the evaluation results

In order to select an optimum Master Plan from among 30 Master Plan alternatives, several types of evaluation were performed at each stage of the selection in the manner mentioned below.

i) Selection of three appropriate Master Plan alternatives from among 30 Master Plan alternatives

The contents of 30 Master Plan alternatives are shown in Table 5.

Evaluation was made on 30 cases (seven types) of Master Plan alternatives in terms of economy and four other evaluation factors (ref. Fig. 2) which were expanded into 15 evaluation elements.

The items to be evaluated involves qualitative matters as well as quantitative matters, therefore, a deterministic evaluation method was thought to be suitable. A 3-rank rating method with three symbols ('a' as superior, 'b' as fair, and 'c' as inferior) was applied to the rating of evaluation items. One of the symbols was determined for each of the evaluation items based on the evaluation criteria, and the items rated 'c' were excluded from further evaluation. In order to maintain flexibility of selection by case, not more than one Master Plan alternative was selected from each of the seven types. Based on this criteria, the top three Master Plan alternatives which had the most 'a' items were selected as the appropriate Master Plan alternatives. The appropriate Master Plan alternatives selected were cases No. 9, No. 13, and No. 19-(2). An outline of each appropriate Master Plan alternative is shown in Table 6.

Table 5 The master plan alternative (30 cases) (Ref: Table 4.8)

Alternative Treatment and Disposal System	Case number	Number of treatment and disposal facilities				Outline of features of the Master Plan alternative	Purposes
		Incineration plant	Compost plant	Final disposal site	Transfer station		
Landfill only	1–(1)			5		Five disposal sites excluding Tung Kru. No limitation of incoming solid waste volume to each disposal site.	To find out suitable destinations of solid waste and to obtain appropriate incoming waste volume to the destination, under limitation of minimum transport cost.
	1–(2)			5		Five disposal sites excluding Tung Kru. Acceptable waste volume is determined according to the disposable volume in each final disposal site.	The appropriate destination and incoming volume to the destination are determined on the basis of disposable volume.
	2–(1)			5	19	The same as case 1–(1), but transport transfer is made.	Evaluation of the effect of transport transfer is attempted.
	2–(2)			5	19	The same as case 1–(2), but transport transfer is made.	- do -
Composting only	3–(1)		9			The existing 3 plants (1,120 ton/day) plus additional 6 plants (each 765 ton/day).	The existing plants will cope with solid waste with same capacity as present: the rest of the solid waste will be treated evenly by the six new plants.
	3–(2)		5			As to the plants with capacity of 300 ton/day or larger, no limitation of incoming volume is made.	To find out suitable destinations and appropriate incoming volume.
	4–(1)		9		17	The same as case 3–(1), but transport transfer is made.	Evaluation of the effect of transport transfer is attempted.
	4–(2)		5		14	The same as case 3–(2), but transport transfer is made.	- do -
Incineration only	5	5				Treatment capacity (possibly aquiring the site area) of each plant is taken into consideration.	Combination to determine cost minimum is sought. In terms of capacity constraints minimum number of sites will be 5.
	6	5			3	The same as case 5, but transport transfer is made.	Evaluation of the effect of transport transfer is attempted.
Composting + landfill	7		3	5		The existing three compost plants cope with 1,120 ton/day: the other volume is landfilled.	Continuation of the existing system.
	8		3	5	19	The same as case 7, but transport transfer is made.	Evaluation of the effect of transport transfer is attempted.
	9		5	5		Demand for compost is assumed 1,920 ton/day. The existing plants are utilized. Surplus waste for composting is landfilled.	Formulation of number, location and capacity of additional plants to satisfy the increased compost demand.
	10		5	5	17	The same as case 9, but transport transfer is made.	Evaluation of the effect of transport transfer is attempted.
Incineration + composting	11	4	3			Total volume of solid waste other than treated in the existing compost plants is incinerated. Therefore, 4 incineration plants are required.	Study of incineration treatment utilizing the existing compost plants.
	12	4	3		6	The same as case 11, but transport transfer is made.	Evaluation of the effect of transport transfer is attempted.
	13	4	5			Compost demand 1,920 ton/day. The existing compost plants are used. Surplus solid waste is incinerated.	To examine establishment of incineration plants and additional compost plants to satisfy increasing compost demand.
	14	4	5		5(1)*	The same as case 13, but transport transfer is made. (One land-to-river transfer station is required.)	Evaluation of the effect of transport transfer is attempted.
Incineration + landfill	15	1		5		Only one incineration plant with capacity of 1,500 ton/day is established at the most suitable place, and excessive waste for incineration is landfilled.	Study of total minimum cost with incineration + landfill. If number of incineration plants becomes two or more, the total cost also increases.
	16	1		5	16	The same as case 15, but transport transfer is made.	Evaluation of the effect of transport transfer is attempted.
Incineration + composting + landfill	17–(1)	1	3	5		Only one incineration plant is established at the most suitable place. The existing compost plants are used. Excessive solid waste for treatment is landfilled.	Combination of the three minimum cost sub-systems (without transfer).
	17–(2)	2	3	5		The same as case 17–(1), but one more incineration plant is added.	Examination of a balance between collection/transport cost and expanded facilities cost from addition of incineration plant. Study of the total cost.
	18–(1)	1	3	5	14	The same as case 17–(1), but transport transfer is made.	Evaluation of the effect of transport transfer is attempted.
	18–(2)	2	3	5	8	The same as case 17–(2), but transport transfer is made.	- do -
	19–(1)	1	5	5		One incineration plant at the most suitable place. Compost demand 1,920 ton/day. Use of the existing compost plants.	Combination of the minimum cost with increased compost demand.
	19–(2)	2	5	5		The same as case 19–(1), but one more incineration plant is added.	Examination of a balance between collection/transport cost and expanded facilities cost from addition of incineration plant. Study of the total cost.
	19–(3)	2	4	3		Increase of capacity of Nong Khaem compost plant. Close down On-Nooch final disposal site.	New compost plant near to Nong Khaem is affiliated with Nong Khaem compost plant. The future land-use on On-Nooch area is considered.
	19–(4)	3	4	3		Incineration plants at three sites. Compost demand 1,920 ton/day. Use of the existing compost plants.	Reduction of landfill disposal volume by increasing disposal capacity of intermediate treatment facilities.
	20–(1)	1	5	5	12	The same as case 19–(1), but transport transfer is made.	Evaluation of the effect of transport transfer is attempted.
	20–(2)	2	5	5	4	The same as case 19–(2), but transport transfer is made.	- do -

* Number in ( ) indicate land-to-river transfer.

Establishment of transfer stations was considered to be an effective means to increase transportation efficiency when solid waste would be transported certain distance (according to the estimation, 12 km or more), but the plans involving the transfer system were abandoned for the following reasons:

1. Transfer stations should be constructed in the city center area, but the suitable sites cannot be acquired in the already urbanized areas or along Ghao Phraya river.

2. Establishment of transfer stations would create new difficulties with operation and maintenance, which cannot be easily quantified or cost evaluated.

3. The transport distance of some alternatives is too short to effectively utilize the transfer system.

Table 6 Outline of appropriate Master Plan alternatives

Type of treatment and disposal	Case No.	Treatment/disposal volume			Location of the facilities and the capacity*		
		Composting	Incineration	Landfilling	Compost plant (t/d)	Incineration plant (t/d)	Landfill site
Compost +Landfill	9	1,630	0	3,910	Existing 4 plants (1,120), Bang Khun Tian (260), Taling Chan (540)	No plant	On-Nooch Nong Khaem Ram Intra
Compost +Incineration	13	1,630	3,910	0	Same as above	Yannawa (1,500) Bang Kapi(1,200) Bangkok Noi (1,100) Phasi Charoen (1,100)	On-Nooch Nong Khaem **
Compost +Incineration +Landfill	19-(2)	1,630	2,400	1,510	Same as above	Yannawa (1,500) Dusit (1,500)	On-Nooch Nong Khaem Ram Intra

Note: * Capacity of each facility was estimated assuming the operating rate of the compost plant to be 0.85 and that for the incineration plant 0.8.

** Landfill sites in case No. 13 are for disposal of intermediate treatment residue.

ii) Economic and financial analyses

a. Economic analysis

The essential benefits of solid waste management are maintenance and improvement of public health and protection of the environment. These benefits are rather difficult to quantitatively measure. In addition to these, there will be many other unmeasurable benefits. In the economic analysis here, economic adequacy of each appropriate Master Plan alternative was evaluated based on quantitatively measurable benefit and cost. The results, therefore, of the economic analysis should be regarded as one of the indices for evaluation of the appropriate Master Plan alternatives.

Benefits were divided into two categories: primary direct benefits and secondary direct benefits. Primary direct benefits are the benefits derived from implementation of solid waste management. If solid waste management were not carried on, public health and the environment would be deteriorated and, as the result, miscellaneous public problems would occur.

Assuming that people bear necessary cost for disposal of their own solid waste in order not to incur the public problems, this cost was regarded as primary direct benefit. On assumption that people dispose of solid waste by landfilling at or nearby their own houses and that they have to purchase the land, the land acquisition cost was considered to represent primary direct benefit. Secondary direct benefits cover the increased products which will be produced from implementation of a new solid waste management system, such as electricity generation, compost sales, utilization of incineration residue (ash), and ferrous metal recovery.

Application of a new solid waste management system also allows the reduction in cost for collection trucks purchase and collection and transportation cost. This reduction was deemed as a cost saving effect and listed in the project cost instead of being added to the secondary direct benefits.

On the cost side, all cost items related to solid waste management including construction and management costs for the new system were included except river and canal cleaning cost and road cleaning cost.

The economic analysis was made on the basis of benefit/cost ratio. No attempt, however, was made to calculate the internal rate of return (IRR) since the annual management cost is considerable when compared with the initial investment cost. The results of economic analysis are shown in Table 7.

Table 7 Results of economic analysis for the period 1983 - 2010

(Unt: million Baht) [1)]

		Case No. 9	Case No. 13	Case No. 19-(2)
Benefit	Primary direct benefit	21,980.0	21,980.0	21,980.0
	Secondary direct benefit	552.8	2,734.6	2,052.4
	Total	22,532.8	24,714.6	24,032.4
Cost	Construction cost	2,654.8	8,390.8	5,735.4
	Land acquisition cost	419.7	467.4	603.8
	Operation and maintenance cost	5,459.5	7,690.6	6,832.0
	Collection & transport cost Vehicle purchase cost	8,145.8	6,928.2	7,261.0
	Total	16,679.8	23,477.0	20,432.2
Benefit cost ratio	Discount rate			
	8%	1.44	1.09	1.15
	10%	1.42	1.05	1.11
	15%	1.39	0.98	1.04

Note 1) Except for benefit cost ratio.

For reference, economic analysis was made on the case that the collection rate should be raised from the current 80% to 97% by the year 2000 but intermediate treatment and final disposal be conducted in the existing treatment/disposal facilities with the current methods (referred to as without-project case). As the result, its benefit/cost ratio was calculated to be 1.48 (with a discount rate 15%).

Thus, in every case, the benefit/cost ratio exceeds 1.0, which verifies the economic adequacy of each appropriate Master Plan alternative. The case which requires the larger economic cost has the smaller B/C ratio. This is because the primary direct benefit does not change in spite of increase of economic cost and increase rate of the secondary direct benefit is smaller than that of the economic cost.

b. Financial analysis

Since this is a particular financial analysis to be made on solid waste management which produces negative added value, the analysis was made based on a viewpoint of how the plan matches BMA's financial condition. In the financial analysis, solid waste collection fees and revenue from resource recovery were considered to be the revenue sources. Financial cost was calculated as a sum of the facilities construction cost, land acquisition cost and all other management costs including collection and transport cost, collection trucks purchase cost, facilities operation and maintenance cost, and ordinary expenditures but excluding river and canal cleaning cost and road cleaning cost. (As for landfill sites, the required capacity until the year 2010 was assumed to be acquired and the costs for facilities construction and land acquisition were considered to be financial cost.)

The result of the financial analysis shows that if the current financial conditions concerning solid waste management is maintained, that is to say, if the present rate 6.6% of the total BMA budget allocated to sanitation enterprise is kept in the future, the appropriate Master Plan alternative case No. 9 alone will become financially feasible, whereas the cases No. 13 and No. 19-(2) have little practicability. As a means to make these two cases feasible, it is thinkable to increase the rate allocated to sanitation enterprise from the present 6.6% of the total BMA budget to 10%; however, it may be impracticable. In order to make both cases No. 13 and No. 19-(2) feasible under the condition that the present rate 6.6% is to be continued in the future, it is essential to raise a fund equivalent to a sum of an amount which accounts for approximately 20% of costs for new facilities construction and land acquisition and an amount which is needed for the major repair of the existing compost plants, by both means of preparing BMA's own fund and requesting the National Government the corresponding subsidy.

In the funding plan, the fund needed for implementation of the project was assumed to be raised from the following sources: an equivalent amount to 20% of the new facilities construction cost from the National Government as subsidy, foreign currency portion of the rest 80% mainly from overseas financial agencies and local currency portion of the same from local city banks as

the loan, and a sum of the cost for major repair of the existing compost plant and the management cost including collection and transport cost from BMA as its own fund.

The project cost, the funding plan of the construction cost and the results of the financial analysis are shown in Tables 8, 9 and 10 respectively.

Table 8 Project cost (Fiscal 1983 - 2000) (Ref. Table 6.50)

(Unit: million Baht)

Cost item	Case		
	No. 9	No. 13	No. 19–(2)
Facilities construction cost	2,848.5	9,551.3	6,457.6
Compost & incineration plants	706.2	8,149.7	4,823.1
Landfill sites	1,439.4	832.4	1,065.3
Parking lots	133.7	–	–
Major repair of the existing compost plants	569.2	569.2	569.2
Land acquisition cost	671.2	747.9	966.2
Compost & incineration plants	115.4	680.4	782.7
Landfill, sites	450.3	67.5	183.5
Parking lots	105.5	–	–
Management cost	7,789.4	7,856.2	7,767.4
Project cost	11,309.1	18,155.4	15,191.2
Without-project case portion	8,596.3	8,596.3	8,596.3
Additional system portion	2,712.8	9,559.1	6,594.9

Table 9 Funding plan (Ref: Table 6.29)

(Unit: million Baht)

Cost item	Case		
	No. 9	No. 13	No. 19–(2)
BMA's own fund (local currency)	1,159.3	2,515.2	1,940.1
Loan from overseas (foreign currency)	268.9	5,622.1	3,182.3
Local loan (local currency)	2,091.5	2,161.9	2,301.4
Total	3,519.7	10,299.2	7,423.8

Table 10 Financial analysis (Fiscal 1983 - 2010) (Ref: Table 6.41, 43 and 46)

(Unit: million Baht)

Item	Case			
	No. 9	No. 13	No. 19–(2)	withput-project
Revenue (solid waste collection fee, resource recovery)	4,467.8	5,719.9	5,318.4	4,288.2
Financial cost	18,007.6	25,915.2	22,422.4	15,040.1
Construction cost	3,519.7	10,299.2	7,423.8	1,024.5
Management cost	14,487.9	15,616.0	14,998.6	14,015.6
Financing burden	15,884.8	21,718.0	19,528.3	10,751.9

iii) Environmental impact assessment

One of the main objectives of a sanitation enterprise is environmental protection. From this point of view, environmental impact assessment plays an important role in the determination of the optimum Master Plan.

In the environmental impact assessment, impact on environment which may be caused by the solid waste disposal system proposed in each appropriate Master Plan alternative was forecast. Then, applying a scoring method, the ranking of the appropriate Master Plan alternatives was made according to relative size of their impact.

The assessment was performed based on the following conditions:-

a. The base year of the assessment is the year 2000, when the proposed disposal system is planned to commence normal operation.

b. The environmental impact sources are collection trucks, the existing and new intermediate treatment facilities, and existing and new final disposal sites.

c. The objects of the assessment are the natural, living and socio-economic environment. 24 environmental phenomena were selected and assessed.

d. The level of impact on the environment caused by each environmental impact source was evaluated in terms of standards. The standards were formulated taking data and information from the environmental quality standards and the emission control standards of Thailand, or citing similar standards of other foreign countries.

e. According to the nature of environmental phenomena, either quantitative or qualitative assessment measurements were made: quantitative measurements for air pollution, water pollution, etc., and qualitative measurements of landscape, scenery and sunshine obstructions and the like.

Environmental impact of the three appropriate Master Plan alternatives was examined based on the above conditions and all of them were found to be acceptable based on the standards. This verifies that, as far as environmental impact is concerned, all cases of appropriate Master Plan alternatives are feasible and do not produce any environmental difficulties.

In order to determine the relative superiority in terms of environmental protection of three appropriate Master Plan alternatives compared to each other, a scoring method was adopted, with which each environmental phenomenon was scored with a positive integral number up to 3 including zero according to size of impact on each environmental phenomenon (score 0: No impact will be given. 1: Small impact will be given, which is far less than the allowable limit. 2: Some impact will be given, which is within the allowable limit. 3: Large impact will be given, which exceeds the allowable limit), and mean value of these scores was taken as the score to represent each Master Plan alternative.

The results of the scoring in Table 11 shows the alternative case No. 13 to be the best, the case No. 19-(2) the second and the

case No. 9 the third. For convenience of comparison, assessment by scoring method was made also on without-project case and the result is shown in Table 11.

Table 11 Score of appropriate Master Plan alternatives

	Case No. 9	Case No. 13	Case No.19-(2)	without-project case
Score	0.873	0.551	0.680	1.175
(Index)	(63)	(100)	(81)	(47)

vi) Evaluation from technological viewpoint

When evaluation of such a huge project as the establishment of a solid waste management system in Bangkok city is required, a technological evaluation is also indispensable, which involves political and administrative practicability as well as technical reliability and up-to-date state-of-the-art technology.
To meet this requirement, evaluation from the technological viewpoint was performed.

The evaluation items were selected as follows:

- From administrative viewpoint, compatibility with the existing solid waste management system, ease of alteration of the plan, organizational adaptability, balance with other urban systems, conformity to administrative vision.

- From technical viewpoint, grade of technical advancement, reliability, treatment effect (inactivation, volume reduction, resource recovery).

Scoring method was applied and scores varying from 1 to 5 were given to the evaluation items upon mutual comparison of each evaluation item of individual appropriate Master Plan alternatives with that of the without-project case.

The results of the evaluation (Table 12) indicated that the case No. 19-(2) is the best from both administrative and technical viewpoints, followed by case No. 13 and case No. 9 respectively.

Table 12 Scores by evaluation from technological viewpoint

	Case No. 9	Case No. 13	Case 19-(2)	without-project case
Administrative viewpoint	3.2	3.2	3.9	3
Technical viewpoint	3.4	4.2	4.33	3

(4) Overall evaluation and selection of the optimum Master Plan

i) Overall evaluation (Selection of an optimum Master Plan from among three appropriate Master Plan alternatives)

Overall evaluation was made based on the output of the three types of evaluation already-performed (viz. economic and financial analyses, environmental impact assessment, and evaluation from technological viewpoint).

For overall evaluation, the deterministic evaluation method was adopted and a scoring method was applied to the rating. Developing the above outputs, two evaluation factors ('economy' and 'environment and technology') and four evaluation elements (B/C, rate of financing burden, environmental protection, and technological viewpoint) were formulated. In order to give scores to different evaluation elements on a common basis, the state of without-project case was set as a base level. The score was determined by mutual comparison of each evaluation element with the state of without-project case. In the same manner as applied to environmental impact assessment, a weight was given to each item according to its relative significance to others.

The results of the overall evaluation are shown in a matrix in Table 13.

ii) The optimum Master Plan

The results of the overall evaluation in the order of priority for the three appropriate Master Plan alternatives were case No. 19-(2) as the best, case No. 9 as the second and case No. 13 as the last. Thus, the appropriate Master Plan alternative case No. 19-(2) was determined to be the optimum Master Plan. An outline of the solid waste management system planned in the optimum Master Plan is described in Table 14. The benefits and effect which will be derived from implementation of the optimum Master Plan are explained below by comparison of the without-project case.

a. Solid waste disposal

- Solid waste collection and transportation cost and vehicle acquisition cost, which contain the largest part of solid waste management cost, will be reduced by 13% and 17% respectively.
- Landfill volume of solid waste will be reduced to one-third.
- Development of intermediate treatment system will enable a reduction in solid waste to be landfilled to 50% by weight.

b. Resource recovery

- Various resource recovery is expected by means of composting, recovery of ferrous metal, electric power generation, utilization of incineration residue (ash), etc.
- It is possible to add a material recovery process to the pre-treatment stage for the new compost plant.

Table 13 Overall evaluation and project outline

PART I

Individual evaluations

Economic and Financial analyses (1983 – 2010) (million Baht)

Item	Case No. 9	Case No. 13	Case No. 19–(2)
Economic analysis			
Economic benefit	22,532.8	24,714.6	24,032.4
Direct benefit	21,980.0	21,980.0	21,980.0
Indirect benefit	552.8	2,734.6	2,052.4
Economic cost	15,906.3	21,165.1	19,207.0
Construction cost	3,074.5	8,858.2	6,339.2
Operation and maintenance cost	11,690.7	12,612.0	12,154.8
General management cost	1,753.5	1,891.7	1,823.3
Salvage value	–612.4	–2,196.8	–1,110.3
B/C	1.39	0.98	1.04
Order	1	3	2
Financial analysis			
Revenue (Solid waste collection fee and resource recovery)	4,467.8	5,719.9	5,318.4
Financial project cost	18,007.6	25,915.2	22,422.4
Construction cost	3,519.7	10,299.2	7,423.8
Operation and maintenance cost	12,598.1	13,579.0	13,042.3
General management cost	1,889.8	2,037.0	1,956.3
Order	1	3	2

Environment and technology

Environmental impact assessment (Year 2000)

Objective environmental phenomena

- Living environment → air pollution, water pollution, noise, rank odour, traffic congestion, etc.
- Natural environment → topography, groundwater, flora, fauna, etc.
- Socio-economic environment → historic spot, cultural assets, land use, industry, etc.

Environmental impact element

- New compost plant, existing compost plant, incineration plant, landfill site, collection truck

Assessment score

Environment impact element	Case No. 9	Case No. 13	Case No. 19–(2)
New compost plant	0.061	0.061	0.061
Existing compost plant	0.077	0.077	0.077
Incineration plant	0	0.352	0.219
Landfill site	0.685	0.020	0.273
Collection truck	0.050	0.041	0.050
Overall	0.873	0.551	0.680
Order	3	1	2

Evaluation from technological viewpoint

Item	Case No. 9	Case No. 13	Case No. 19–(2)	Weight w_i
Score of evaluation from technical viewpoint				
Grade of technical advancement a_1	4	5	5	0.4
Reliability a_2	3	3	3.5	0.4
Treatment effect a_3	3	5	4.67	0.2
Overall ($\Sigma a_i w_i$)	3.4	4.2	4.33	
Order	3	2	1	
Score of evaluation from administrative viewpoint				
Compatibility with the existing solid waste management system a_4	3	3	3	0.2
Ease of alteration of the plan a_5	3	2	3	0.2
Organizational adaptability a_6	3	3	3.5	0.2
Balance with other urban systems a_7	4	5	5	0.2
Conformity to administrative provision a_8	3	3	5	0.2
Overall ($\Sigma a_i w_i$)	3.2	3.2	3.9	
Order	2	2	1	

Conversion of evaluation standard level

PART II

Overall evaluation matrix

Case No.	Order	Score: Overall evaluation S	Economy Sx	Economy: B/C Sx_1	Economy: Rate of financing burden Sx_2	Environment and technology Sy	Environmental protection Sy_1	Technological viewpoint Sy_2	Administrative viewpoint Sy_{21}	Technical viewpoint Sy_{22}
9	2	108	94	94	93	121	126	115	110	120
13	3	107	70	66	74	144	153	135	110	160
19–(2)	1	114	77	70	84	150	144	156	145	167
Weight of evaluation items			Wx 0.5	Wx_1 0.5	Wx_2 0.5	Wy 0.5	Wy_1 0.5	Wy_2 0.5	Wy_{21} 0.5	Wy_{22} 0.5

$S = W_x S_x + W_y S_y$

$S_x = W_{x_1} S_{x_1} + W_{x_2} S_{x_2}$ $S_y = W_{y_1} S_{y_1} + W_{y_2} S_{y_2}$, $S_{y_2} = W_{y_{21}} S_{y_{21}} + W_{y_{22}} S_{y_{22}}$

PART III

Outline of solid waste management system for the year 2000

Item			Case No. 9	Case No. 13	Case No. 19–(2)
Solid waste disposal plan (ton per day on a solid waste basis) (percent in parentheses)	Compost plant	Existing	950	950	950
		New	680	680	680
		Subtotal	1,630 (29)	1,630(29)	1,630(29)
	Incineration plant		0 (0)	3,910(71)	2,400(43)
	Landfill site		3,910 (71)	0(0)	1,510(28)
	Total		5,540 (100)	5,540(100)	5,540(100)
Facilities	Compost plant	Number	6	6	6
		Capacity (t/d)	1,920	1,920	1,920
	Incineration plant	Number	0	4	2
		Capacity (t/d)	0	4,900	3,000
	Landfill site	Number	3	3	3
		Incoming volume (t/d)	4,081	953	2,161
	Parking lot	Number	2	2	2
		Size (trucks)	800	600	600
Equipment (unit)	Collection and transport	Collection trucks	1,374	1,139	1,164
		Incineration residue transport truck	0	42	26
	Compost plant and landfill work	Bulldozer	22	17	18
		Front-end loader	14	14	14
		Dump truck	19	18	18
		Others	29	29	29
	Road cleaning	Mech. road sweeper	21	21	21
		Water sprinkler truck	21	21	21
		Dump truck	21	21	21
		Crane-attached compactor	25	25	25
	River and canal cleaning	Mech. cleaning boat	5	5	5
		Boat	110	110	110
		Dump truck	25	25	25
Man power (person)	Collection and transport	Driver	1,499	1,254	1,274
		Driver (residue transp.)	0	46	28
		Worker	4,438	3,671	3,758
	Plant	Worker, operator	426	707	586
	Landfill site	Worker	133	65	75
	Road cleaning	Driver, assistant	167	167	167
		Sweeper	3,740	3,740	3,740
	River and canal cleaning	Boat worker	389	389	389
		Driver, worker	550	550	550
	Engineer (head office and branches)		43	85	63
	Office (head office and branches)		502	493	482
	Worker (head office)		170	182	177
	Total		12,057	11,340	11,289

PART I

Individual evaluations

Economic and Financial analyses (1983 – 2010) (million Baht)

Item	Case No. 9	13	19–(2)
Economic analysis			
Economic benefit	22,532.8	24,714.6	24,032.4
Direct benefit	21,980.0	21,980.0	21,980.0
Indirect benefit	552.8	2,734.6	2,052.4
Economic cost	15,906.3	21,165.1	19,207.0
Construction cost	3,074.5	8,858.2	6,339.2
Operation and maintenance cost	11,690.7	12,612.0	12,154.8
General management cost	1,753.5	1,891.7	1,823.3
Salvage value	−612.4	−2,196.8	−1,110.3
B/C	1.39	0.98	1.04
Order	1	3	2
Financial analysis			
Revenue (Solid waste collection fee and resource recovery)	4,467.8	5,719.9	5,318.4
Financial project cost	18,007.6	25,915.2	22,422.4
Construction cost	3,519.7	10,299.2	7,423.8
Operation and maintenance cost	12,598.1	13,579.0	13,042.3
General management cost	1,889.8	2,037.0	1,956.3
Order	1	3	2

Environment and technology

Environmental impact assessment (Year 2000)

Objective environmental phenomena

- Living environment → air pollution, water pollution, noise, rank odour, traffic congestion, etc.
- Natural environment → topography groundwater, flora, fauna, etc.
- Socio-economic environment → historic spot, cultural assets, land use, industry, etc.

Environmental impact elements

New compost plant, existing compost plant, incineration plant, landfill site, collection truck

Assessment score

Environment impact element	Case No. 9	13	19–(2)
New compost plant	0.061	0.061	0.061
Existing compost plant	0.077	0.077	0.077
Incineration plant	0	0.352	0.219
Landfill site	0.685	0.020	0.273
Collection truck	0.050	0.041	0.050
Overall	0.873	0.551	0.680
Order	3	1	2

Evaluation from technological viewpoint

Item	Case No. 9	13	19–(2)	Weight w_i
Score of evaluation from technical viewpoint				
Grade of technical advancement a_1	4	5	5	0.4
Reliability a_2	3	3	3.5	0.4
Treatment effect a_3	3	5	4.67	0.2
Overall ($\Sigma a_i w_i$)	3.4	4.2	4.33	
Order	3	2	1	
Score of evaluation from administrative viewpoint				
Compatibility with the existing solid waste management system a_4	3	3	3	0.2
Ease of alteration of the plan a_5	3	2	3	0.2
Organizational adaptability a_6	3	3	3.5	0.2
Balance with other urban systems a_7	4	5	5	0.2
Conformity to administrative vision a_8	3	3	5	0.2
Overall ($\Sigma a_i w_i$)	3.2	3.2	3.9	
Order	2	2	1	

Conversion of evaluation standard level

PART II

Overall evaluation matrix

Case No.	Order	Score: Overall evaluation S	Economy: Sx	B/C Sx_1	Rate of financing burden Sx_2	Environment and technology: S_Y	Environmental protection S_{Y_1}	Technological viewpoint S_{Y_2}	Administrative viewpoint $S_{Y_{21}}$	Technical viewpoint $S_{Y_{22}}$
9	2	108	94	94	93	121	126	115	110	120
13	3	107	70	66	74	144	153	135	110	160
19–(2)	1	114	77	70	84	150	144	156	145	167
			Wx	Wx_1	Wx_2	W_Y	W_{Y_1}	W_{Y_2}	$W_{Y_{21}}$	$W_{Y_{22}}$
			0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
			Weight of evaluation items							

$S = W_X S_X + W_Y S_Y$

$S_X = W_{X_1} S_{X_1} + W_{X_2} S_{X_2}$

$S_Y = W_{Y_1} S_{Y_1} + W_{Y_2} S_{Y_2}$, $S_{Y_2} = W_{Y_{21}} S_{Y_{21}} + W_{Y_{22}} S_{Y_{22}}$

Table 13 Overall evaluation and project outline

PART III

Outline of solid waste management system for the year 2000

Item			Case No. 9	13	19–(2)
Solid waste disposal plan (ton per day on a solid waste basis) (percent in parentheses)	Compost plant	Existing	950	950	950
		New	680	680	680
		Subtotal	1,630 (29)	1,630(29)	1,630(29)
	Incineration plant		0 (0)	3,910(71)	2,400(43)
	Landfill site		3,910 (71)	0(0)	1,510(28)
	Total		5,540 (100)	5,540(100)	5,540(100)
Facilities	Compost plant	Number	6	6	6
		Capacity (t/d)	1,920	1,920	1,920
	Incineration plant	Number	0	4	2
		Capacity (t/d)	0	4,900	3,000
	Landfill site	Number	3	3	3
		Incoming volume (t/d)	4,081	953	2,161
	Parking lot	Number	2	2	2
		Size (trucks)	800	600	600
Equipment (unit)	Collection and transport	Collection trucks	1,374	1,139	1,164
		Incineration residue transport truck	0	42	26
	Compost plant and landfill work	Bulldozer	22	17	18
		Front-end loader	14	14	14
		Dump truck	19	18	18
		Others	29	29	29
	Road cleaning	Mech. road sweeper	21	21	21
		Water sprinkler truck	21	21	21
		Dump truck	21	21	21
		Crane-attached compactor	25	25	25
	River and canal cleaning	Mech. cleaning boat	5	5	5
		Boat	110	110	110
		Dump truck	25	25	25
Man power (person)	Collection and transport	Driver	1,499	1,254	1,274
		Driver (residue transp.)	0	46	28
		Worker	4,438	3,671	3,758
	Plant	Worker, operator	426	707	586
	Landfill site	Worker	133	65	75
	Road cleaning	Driver, assistant	167	167	167
		Sweeper	3,740	3,740	3,740
	River and canal cleaning	Boat worker	389	389	389
		Driver, worker	550	550	550
	Engineer (head office and branches)		43	85	63
	Office (head office and branches)		502	493	482
	Worker (head office)		170	182	177
	Total		12,057	11,340	11,289

Table 14 Outline of solid waste management system of optimum Master Plan (the year 2000)
(Ref: Table 8.8)

Solid waste disposal plan (incoming solid waste basis) (t/d)				Remark
Compost plant	1,630	(29%)		Compost products 245 t/d
Incineration plant	2,400	(43%)		Electricity generation 401,280 kWh/d
Final disposal site	1,510	(28%)		
Total	5,540	(100%)		

Facilities Plan

Facilities	Treatment/disposal volume (t/d)	Capacity (t/d)	Location	
Compost plant (1)	540	640	On-Nooch (1)(2)	The existing
Compost plant (2)	270	320	Ram Intra	The existing
Compost plant (3)	217	260	Bang Khun Tian	Operation from fiscal 1998
Compost plant (4)	463	540	Taling Chan	Operation from fiscal 2000
Compost plant (5)	140	160	Nong Khaem	The existing
Incineration plant (1)	1,200	1,500	Yannawa	Operation from fiscal 1990 Residue is transported to On-Nooch
Incineration plant (2)	1,200	1,500	Dusit	Operation from fiscal 1995 Residue is transported to Nong Khaem
Final disposal site (1)	520	857	On-Nooch	The existing. 164,000 m² extension by 2010.
Final disposal site (2)	740	1,005	Nong Khaem	The existing. 263,000 m² extension by 2010.
Final disposal site (3)	250	299	Ram Intra	Operation from fiscal 1988. 388,000 m² extension by 2010
Parking lot (1)	–	300 trucks	Yannawa	Constructed in incineration plant site.
Parking lot (2)	–	300 trucks	Dusit	Constructed in incineration plant site.

Equipment plan

Collection transport	Collection trucks	1,164 units	Reserved trucks 5%
	Incineration residue transport trucks	26	Reserved trucks 5%
Road sweeping	Mech. road sweepers	21	
	Other vehicles	67	Water sprinkler, dump truck, etc.
River and canal cleaning	Mech. cleaning boats	5	Owned by BSD
	Boats	110	
	Dump trucks	25	
Composting & Landfill work	Bulldozer	18	
	Front-end loader	14	
	Dump truck	18	
	Other vehicles	29	Jeep, sterilization truck, etc.

Manpower plan

BOS. ; District				Head office	344
Officer	482 person			Plants, final disposal sites	753
Engineer	63			Collection and transport	9,253
Worker	9,805	Driver	1,397	Total	10,350
		Collector	3,830		
		Sweeper	3,740		
		Others	838		
Subtotal	10,350				
BSD				Mech. boat	29
Boat Worker	389			Boat	360
Driver & Worker	550			Land work	550
Subtotal	939			Total	939
Total	11,289				

c. Economy

- Benefit/cost ratio (B/C) is larger than 1, that verifies the plan to be economically viable.

- Implementation of the plan within BMA's financial capacity is practicable provided that a sum of an amount equivalent to 20% of the construction cost and an amount needed for major repair of the existing compost plants is raised by both means of subsidy from Government of Thailand and provision from BMS's own fund.

d. Environmental protection

. Impact on environment which will be caused by this plan is within an acceptable range. Implementation of this plan is not only feasible from the environmental point of view, but also will contribute to improvement of environmental quality.

e. Technology

. This plan assures smooth operation of a technically-advanced and reliable solid waste management system.

. This plan is highly compatible with the existing solid waste management system and highly flexible which permits modification or alteration of the plan as required.

. Implementation of this plan may encourage development and upgrading of other urban systems.

(5) Implementation schedule and the project cost

The implementation schedule for the optimum Master Plan was formulated as shown in Table 15. In order to avoid prolongation of a unit implementation period or expansion of financing burden as well as to facilitate the implementation, the entire process of implementation was divided into four stages. The period from fiscal 1983 to 1985 was specified as the preliminary stage during which preparation for the implementation will be made, and the following stage from 1986 to 2000 was divided into three 5-year periods, which were designated stage 1, stage 2 and stage 3. Each of these three stages is able to be implemented as an independent project.

A collection trucks distribution plan and man power plan by year for each stage are also attached to the implementation schedule.

The project cost by year for each stage is shown in Table 16. 43% of the total project cost (15,191.2 million Baht) is the cost required for establishment of the new system and the remaining 57% is the portion which corresponds to the cost needed for continuation of the existing system (the without-project case). Disposal plan and flow of solid waste disposal (the year 2000) are shown in Figures 3 and 4.

(6) Matters to be considered prior to implementation

a. Compost problems

The only solution for compost problems is to enlarge the sales market. For realizing this goal, three items (viz. improvement of compost quality, promotion of compost use, and establishment of a reasonable compost price) are the most important factors,

Construction of new compost plants scheduled in stage 3 should be implemented after solution of the compost problems; however, apart from sales of compost as soil improvement material, it should be noted that composting is one of the most effective intermediate treatment measures to contribute to volume reduction and inactivation of solid waste. From this point of view, the composting process is considered highly effective, and utilization of the processed material (compost) in other ways than as a soil improvement material, such as use of it for land reclamation, should be encouraged.

b. Immediate acquisition of landfill sites

It is desirable to acquire landfill sites immediately in anticipation of use of them for tens of years in the future.

Solid waste landfill has such drawbacks as not only requiring a wider landfill area but also having considerable impact on environment. Therefore, volume reduction and inactivation of solid waste by intermediate treatment before placing as landfill are the essential processes to reduce the burden on landfill sites and to fully utilize the limited land areas.

c. Anticipated acquisition of incineration plant construction site

Every proposed site for construction of an incineration plant is located on the outskirts of the city where urbanization is progressing rapidly. It is desirable, therefore, to acquire the proposed site as early as possible.

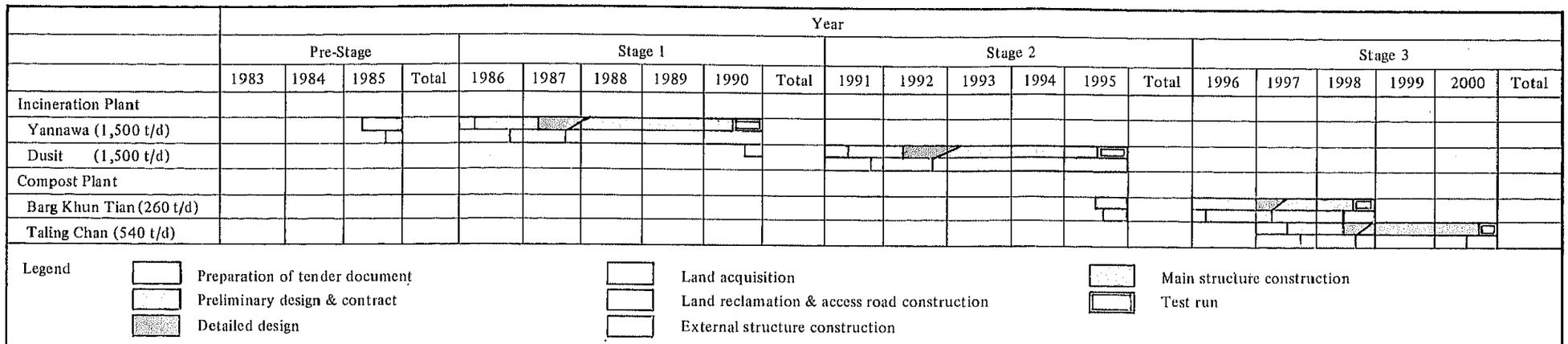
d. Review of the optimum Master Plan

It is recommended to review the optimum Master Plan at the end of each implementation stage in order to examine the suitability of the Plan for further execution.

e. Citizen cooperation

One ultimate factor related to the successful completion of the project is citizen cooperation.

Table 15 Construction and manpower schedule (Ref: Table 8.9)



Note: The number in bar show the section number to be used for landfilling. Section facilities such as the piping for leachate collection will be continuously constructed.

Number of trucks																						
to be purchased	63	40	39	142	40	45	46	46	46	223	39	82	102	123	103	449	103	111	121	116	115	566
in possession	585	618	650	–	683	721	745	769	793	–	780	810	855	892	939	–	969	1,005	1,051	1,108	1,164	–

Note: The trucks include collection trucks such as compactor, non-compactor and container-loader, and spare trucks.

Number of officers	308	311	318	–	326	339	350	360	373	–	380	385	393	408	423	–	428	437	454	465	482	–
(net increase)	0	3	7	10	8	13	11	10	13	55	7	5	8	5	15	50	5	9	7	11	17	59
Number of engineers	13	17	21	–	27	31	36	41	41	–	43	46	46	51	58	–	58	58	60	60	63	–
(net increase)	1	4	4	9	6	4	5	5	0	20	2	3	0	5	7	17	0	0	2	0	3	5
Number of workers																						
Drivers	579	628	664	–	704	760	784	810	850	–	856	866	933	1,006	1,093	–	1,106	1,176	1,251	1,327	1,397	–
(net increase)	33	49	36	118	40	56	24	26	40	186	6	10	67	73	87	243	13	70	75	76	70	304
Collectors	2,306	2,388	2,486	–	2,604	2,752	2,786	2,820	2,856	–	2,861	2,865	2,895	3,068	3,215	–	3,300	3,441	3,580	3,715	3,830	–
(net increase)	45	82	98	225	118	148	34	34	36	370	5	4	30	173	147	359	85	141	139	135	115	615
Sweepers	2,760	2,770	2,780	–	2,790	2,800	2,850	2,900	2,950	–	3,000	3,070	3,140	3,210	3,280	–	3,350	3,440	3,540	3,640	3,740	–
(net increase)	0	10	10	20	10	10	50	50	50	170	50	70	70	70	70	330	70	90	100	100	100	460
Others	348	356	372	–	374	403	409	424	500	–	500	501	507	585	595	–	595	595	674	674	838	–
(net increase)	55	8	16	79	2	29	6	15	76	128	0	1	6	78	10	95	0	0	79	0	164	243

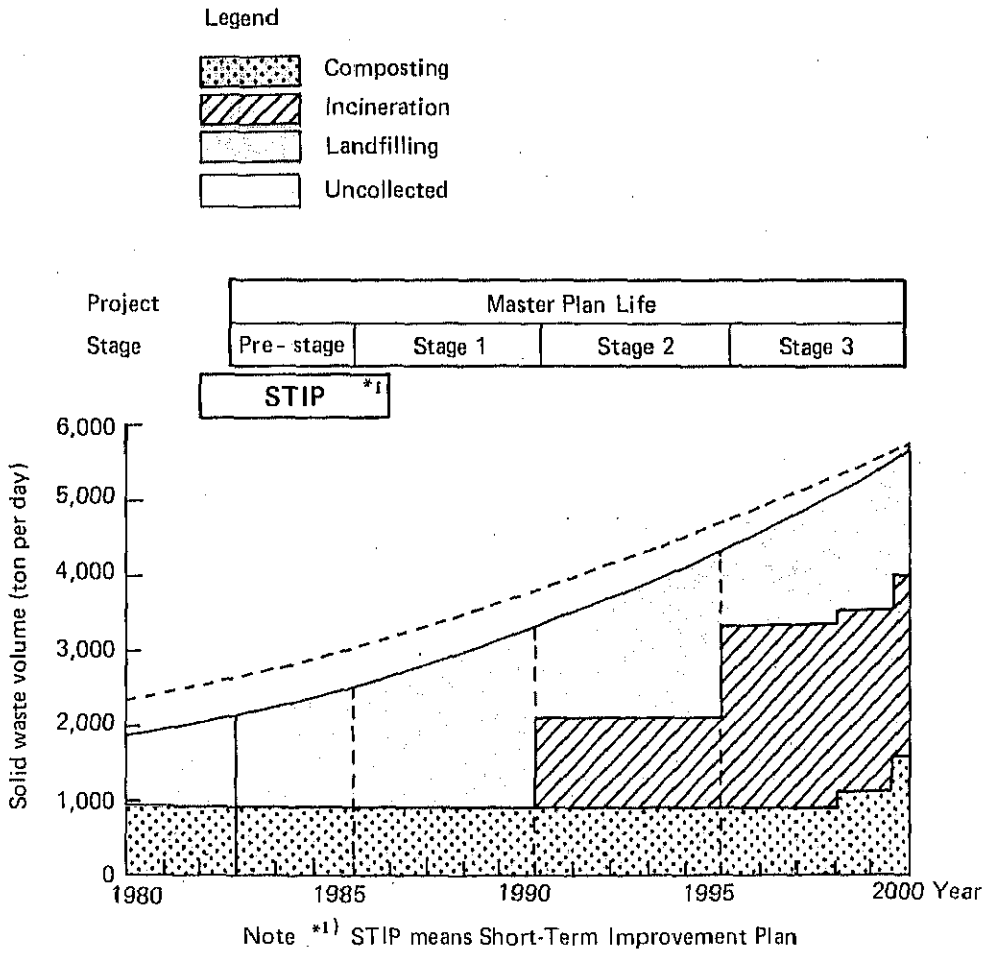
Table 16 Summary of project costs (Ref: Table 8.10)

(Unit: million Baht)

		Year																						Total
		Pre-Stage				Stage 1						Stage 2						Stage 3						
		1983	1984	1985	Total	1986	1987	1988	1989	1990	Total	1991	1992	1993	1994	1995	Total	1996	1997	1998	1999	2000	Total	
Facilities construction cost	T	155.1		4.6	159.7	13.7	288.3	922.8	797.4	494.0	2,516.2	5.2	240.3	959.9	796.5	206.8	2,208.7	37.7	142.1	300.7	145.4	947.1	1,573.0	6,457.6
	F/C	8.7		3.7	11.9		162.5	584.0	576.3	334.4	1,657.2		160.1	586.6	576.3	144.0	1,467.0	6.6	52.5	78.6	61.2	293.3	492.2	3,628.3
	L/C	146.9		0.9	147.8	13.7	125.8	338.8	221.1	159.6	859.6	5.2	80.2	373.3	220.2	62.8	741.7	31.1	89.6	222.1	84.2	653.8	1,080.8	2,829.3
Plant	T			4.6	4.6	9.8	253.0	797.4	797.4	209.4	2,067.0	5.2	240.3	796.5	796.5	206.8	2,045.3	37.7	142.1	197.4	145.4	183.6	706.2	4,823.1
	F/C			3.7	3.7		160.1	576.3	576.3	147.7	1,460.4		160.1	576.3	576.3	144.0	1,456.7	6.6	52.5	72.0	61.2	76.6	268.9	3,189.7
	L/C			0.9	0.9	9.8	92.9	221.1	221.1	61.7	606.6	5.2	80.2	220.2	220.2	62.8	588.6	31.1	89.6	125.4	84.2	107.0	437.3	1.633.4
Final disposal site	T	155.1			155.1	3.9	35.3	125.4			164.6			163.4			163.4			103.3		478.9	582.2	1,065.3
	F/C	8.2			8.2		2.4	7.7			10.1			10.3			10.3			6.6		30.0	36.6	65.2
	L/C	146.9			146.9	3.9	32.9	117.7			154.5			153.1			153.1			96.7		448.9	545.6	1,000.1
Major repair of the existing compost plant	T									284.6	284.6											284.6	284.6	569.2
	F/C									186.7	186.7											186.7	186.7	373.4
	L/C									97.9	97.9											97.9	97.9	195.8
Land acquisition cost	L/C			71.0	71.0	336.0					336.0	312.5		45.0		23.2	380.7	15.4	76.8			86.3	178 5	966.2
Plant	L/C			71.0	71.0	283.8					283.8	312.5				23.2	335.7	15.4	76.8				92.2	782.7
Final disposal site	L/C					52.2					52.2			45.0			45.0					86.3	86.3	183.5
Management cost	T	273.8	301.3	324.5	899.6	349.5	335.6	343.4	350.2	365.7	1,744.4	377.2	424.9	456.2	510.6	513.0	2,281.9	522.3	537.5	568.0	594.1	619.6	2,841.5	7 767.4
	F/C	66.6	77.1	80.6	224.3	84.0	75.0	79.0	79.8	81.9	399.7	91.3	125.1	144.0	176.8	168.7	705.9	180.3	183.4	198.7	205.1	210.0	977.5	2,307.4
	L/C	207.2	224.2	243.9	675.3	265.5	260.6	264.4	270.4	283.8	1,344.7	285.9	299.8	312.2	333.8	344.3	1,576.0	342.0	354.1	369.3	389.0	409.6	1,864.0	5,460.0
Total project cost	T	428.9	301.3	400.1	1,130.3	699.2	623.9	1,266.2	1,147.6	859.7	4,596.6	694.9	665.2	1,461.1	1,307.1	743.0	4,871.3	575.4	756.4	868.7	739.5	1,653.0	4,593.0	15,191.2
	F/C	74.8	77.1	84.3	236.2	84.0	237.5	663.0	656.1	416.3	2,056.9	91.3	285.2	730.6	753.1	312.7	2,172.9	186.9	235.9	277.3	266.3	503.3	1,469.7	5,935.7
	L/C	354.1	224.2	315.8	894.1	615.7	386.4	603.2	491.5	443.4	2,539.7	603.6	380.0	730.5	554.0	430.3	2,698.4	388.5	520.5	591.4	437.2	1,149.7	3,123.3	9.255.5
Without-project case portion	T	270.7	298.2	321.4	890.3	423.1	332.5	343.0	357.1	657.2	2,112.9	396.2	423.1	517.3	488.8	502.1	2,327.5	820.0	521.0	531.8	543.4	849.4	3,265.6	8,596.3
Additional system portion	T	158.2	3.1	78.7	240.0	276.1	291.4	923.2	770.5	202.5	2,483.7	298.7	242.1	943.8	818.3	240.9	2,543.8	△244.6	235.4	336.9	196.1	803.6	1 327.4	6 594.9

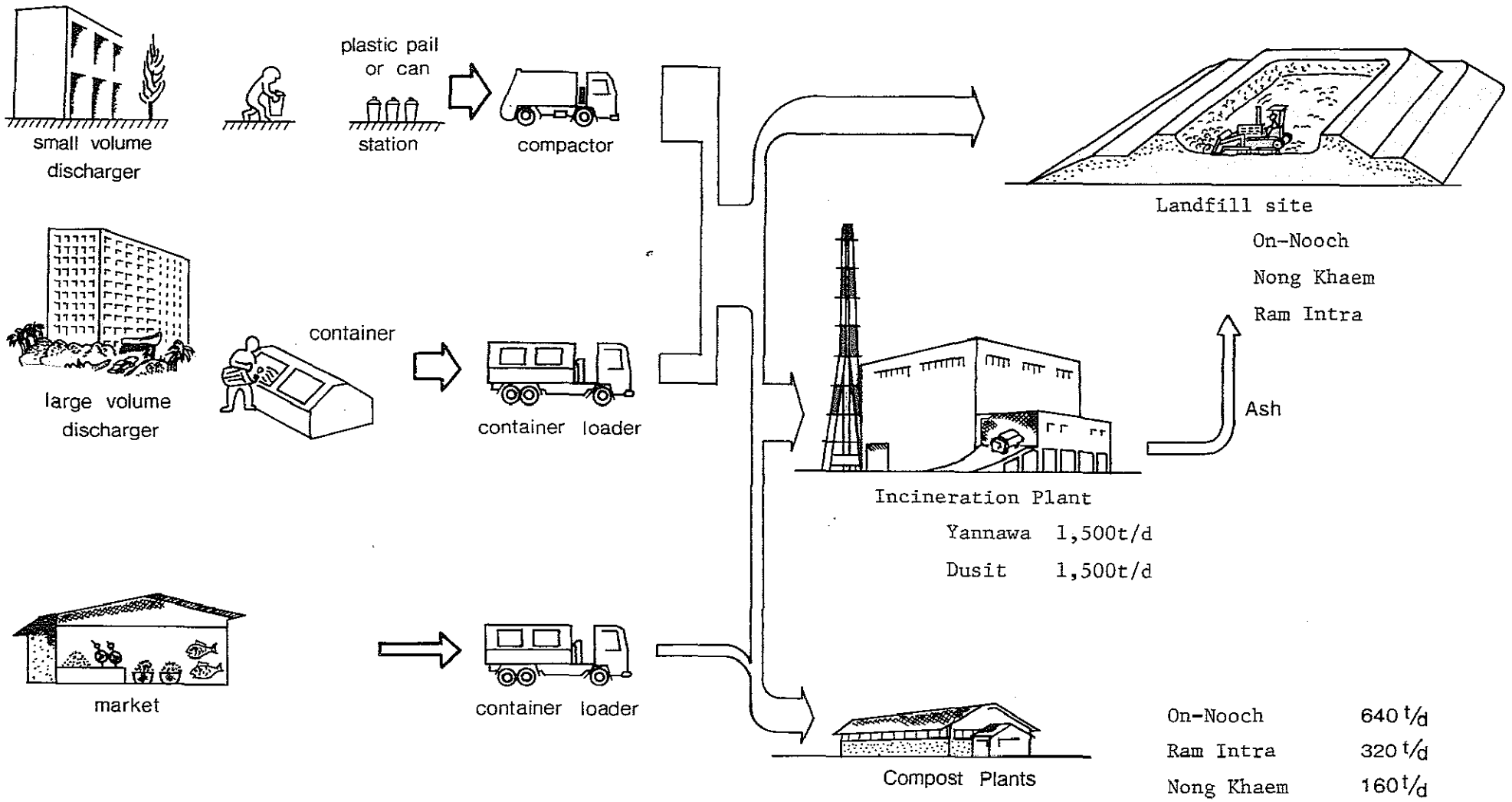
Note: T: Total
F/C: Foreign currency
L/C: Local currency

Fig. 3 Disposal plan of solid waste (Ref: Fig. 8.2)



Note *1) STIP means Short-Term Improvement Plan

Fig. 4 Flow of solid waste disposal (the year 2000) (Ref: Fig. 8.3)



Note: .Collection volume in the year 2000 is 5,540 tons per day the basis of 365 days in a year.
.The figures attached to the names of the facilities show the capacity.

IV Recommendations for Administrative Organizations and Services

Recommendations for smooth implementation of solid waste management were proposed as summarized below.

(1) Systematization of laws and regulations

Laws and regulations related to solid waste management are not well-systematized, causing obstructions in the execution of sanitation administration. Establishment of a basic law for solid waste management should be requested to the National Government.

(2) Management of sanitation utility enterprise

Sanitation utility enterprise should be maintained mainly by BMA's direct management system except for some parts which are entrusted to private disposal companies.

The part to be entrusted in the begining will be solid waste collection and transport for particular areas such as slums, sparsely populated areas, and commercial streets. The part will be extended in due time to operation of intermediate treatment facilities and landfill work.

(3) Reorganization of administrative organization and the administration execution system

Under the existing administrative organization, authority concerning execution of sanitation administration is decentralized to each District, that causes imbalance of collection service among the Districts and incurs difficulties in overall coordination and control of the entire sanitation organization in BMA. In order to avoid such deficiency, all powers concerning sanitation administration which have been empowered to each District should be centralized to BOS and sanitation enterprise in Bangkok city should be executed under a unified control by BOS.

In the future, when any trouble with the control system caused by excessive growth of the organization is feared, several branch offices of BOS should be established, each of which functions as regional agency of BOS and takes charge of sanitation administration in districts in the region. At the same time, it is desirable to establish a general bureau in BMA, which controls enterprises related to environmental protection from overall viewpoints.

(4) Solid waste collection fee

The fee collection rate has been extremely low. (In the fiscal 1980, only 19.2% of the fees were collected.) Reorganization of the fee collection system and any other possible means to increase the collection rate should be undertaken. When revision of the collection fee is considered in the future, the fee should be determined not only on the basis of solid waste management cost but also as a political decision based on a balance with other public utility charges such as electricity and water supply fees.

(5) Disposal of business waste

In principle, enterprises should assume responsibility for disposal of solid waste discharged through their business activities. (Responsibility for self-disposal of business waste.) The enterprises should be made thoroughly aware of this responsibility. On the other hand, BMA is requested to always know the state of the actual business waste being disposed and to establish business waste disposal standards, based upon which the necessary precautional measures should be taken to prevent the occurrence of environmental problems.

(6) Establishment of technical organization

Establishment of a technical organization is essential for modernization of sanitation administration. To this end, BMA is requested to recruit experts in miscellaneous technical fields, to broaden its administrative knowledge and vision. The means of such staffing should include recruitment of technical personnel, specific training, invitation of foreign experts, and so forth.